IMPO EMISSIONS CALCULATOR
TECHNICAL DOCUMENTATION
AND USER GUIDE

INDIANAPOLIS METROPOLITAN PLANNING ORGANIZATION

MPO

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1.0 Introduction

In 2014, Cambridge Systematics, Inc. developed an emissions calculator for the Indianapolis Metropolitan Planning Organization (IMPO) to support its selection of projects for Congestion Mitigation and Air Quality (CMAQ) funding and to assist in annual CMAQ reporting after project authorization. The calculator was adapted from a similar tool developed for the Atlanta Regional Commission (ARC), with all strategies customized to Indianapolis regional conditions and several new strategies created. It also included locally developed emission rates based on EPA's MOVES vehicle emissions model. In addition to CMAQ applications, the tool can be used for other purposes, such as estimating emissions for off-model projects in conformity determinations or evaluating smaller-scale projects for prioritization.

The calculator estimates emissions reductions associated with the eight-hour ozone standard (ozone precursors NOx and VOC), annual PM2.5 standard (PM2.5, NOx, and SO2), one-hour and eight-hour carbon monoxide standard (CO), and greenhouse gases (CO_2, CH_4, and N_2O combined into GHG equivalent units). Emissions benefits were originally calculated for any year between 2015 and 2025, with 11 transportation strategies grouped into three emphasis areas: (1) Roadway ITS/Operations, (2) Transit Start-up Operations and Expansion, and (3) Travel Demand Management.

During the summer of 2025, the Indianapolis Metropolitan Planning Organization (IMPO) engaged the Corradino Group to enhance the emission calculator in several ways:

- Emission Rates Update – Replaced the old 2015 and 2025 MOVES rates with the most recent MOVES5-based emission rates for 2025 and 2035. These rates were developed from county-scale MOVES runs for Marion County, Indiana, using the latest datasets provided by IMPO.

- Methodology Streamlining – Replaced the previous HCM-based delay estimation method with a more effective and flexible approach using travel time and delay results that can be directly estimated by engineers using standard traffic capacity analysis software (e.g., Synchro, SIDRA, etc.). The updated calculator also consolidated the original Sections 2.3a–d (various intersection improvement strategies) and 2.4 (roundabout improvement) into a new single Section 2.3.

- Adjustments for all strategy types – Updated other strategy tabs and calculations to ensure compatibility with the new 2025 and 2035 emission rates.

Chapters 2 to 4 of this document provide updated guidance on using each strategy under the three emphasis areas, while Chapter 5 describes the preparation process of MOVES5 emission rates, updated variables, and relevant source and parameter notes.

It is noted that the following improvement strategies are not included in this update, so no changes are made to corresponding chapters/sections, except for minor adjustments made to ensure working properly with the new 2025 and 2035 emission rates.

- 2.1 – Advanced Traffic Management Systems (ATMS)

- 3.0 – Transit Start-Up Operations and Expansion

- 4.0 – Travel Demand Management

2.0 Roadway ITS/Operations/Incident Management

2.1 Advanced Traffic Management Systems (ATMS)

Project Types

This approach evaluates the emission benefits of adding an advanced traffic management system (ATMS) along a corridor. For the purpose of this strategy basic ATMS is defined as collecting real time traffic data from cameras, speed sensors, etc., sending it to a Transportation Management Center (TMC) where it is analyzed and then actions are taken that can reduce delay (traffic routing, messages posted on dynamic message signs public websites etc., signal timing is manually updated). The proposed project should have the effect of reducing the average delay at intersections through better signal timing, conveying traffic information to the public resulting in better route choice, etc. Installing sensors/communications equipment that only provides data that is not acted upon will not improve average delay or reduce emissions.

Projects that install adaptive signal systems are also included in this strategy since they use similar equipment to collect real-time traffic information. However, different delay reduction assumptions are used since adaptive signals achieve higher delay reduction through software/algorithms that automatically adjust the signal timing in real time based on changing conditions.

Methodology Limitations

ATMS are a fairly new technology with new innovations being frequently applied. Up-to-date research and case studies should be consulted to ensure delay reduction assumptions are accurate and appropriate for the ATMS improvement.

This calculator predicts the overall emission benefits based on the average reduction in delay; therefore, the project under analysis must have an effect on delay.

User-Defined Inputs

The methodology requires the set of project-specific, user-defined inputs presented in Table 2.1. Table 2.2 provides intersection control delay associated with varying levels of service to help the user in selecting a general delay value if more detailed information is not available.

Table 2.1   ATMS Project User-Defined Inputs

User-Defined Input	Default Values	Input Guidance
Scenario Year		• Select a year between 2025 and 2035. The calculator cannot handle years outside this range.
Average Peak Hour Intersection Delay before ATMS (s/veh)	80	• Enter the peak hour intersection delay averaged over all intersections in the entire corridor. • Table 2.2 below can be used to help select general values when detailed values are not available from other sources. • 80 seconds/vehicle is the control delay at a LOS F signalized intersection and can be used as the default value if the intersection is known to be highly congested. Higher values may be entered if supported by a recent study.
Average Peak Hour Intersection Delay after ATMS (s/veh) - optional		• If known, enter the peak hour intersection delay after ATMS installation averaged over all intersections in the entire corridor. If not know leave blank and built in delay reduction constants will be used instead. • If entered it will over-ride the built in delay reduction constants. • This would likely come from Synchro or other traffic signal software.
Peak Hour Volume Along Corridor		• Enter the total peak hour volume along the corridor under analysis. • Obtain from traffic counts or travel demand model.
Truck percent		• Enter the average percentage of trucks in the corridor. • Obtain from traffic counts or travel demand model.
Does the Project Include an Adaptive Signal System?		• If the project is an adaptive signal system, enter 'Y," otherwise enter 'N'.
Number of Intersections along Corridor		• Enter the total number of intersections along the corridor under analysis.

Table 2.2   Level of Service Criteria for Signalized Intersections (HCM 2000)

Level of Service (LOS)	Control Delay (Seconds per Vehicle)	General Description
A	≤ 10	Free-flow
B	> 10-20	Stable Flow (slight delays)
C	> 20-35	Stable Flow (acceptable delays)
D	> 35-55	Approaching unstable flow (tolerable delay, occasionally wait through more than one signal cycle before proceeding)
E	> 55-80	Unstable flow (intolerable delay)
F	> 80	Forced flow (jammed)

Methodology

The purpose of ATMS is to improve travel time, flow, and safety along a corridor. These technological improvements are installed at most, if not all, intersections along a corridor to provide real-time traffic data. This data can subsequently affect signal timings, driver route choice, and other factors that reduce delay along a corridor.

The calculation for predicting emission reductions for this improvement is based on the average decrease in intersection delay. From several cases around the country basic ATMS reduced delay between 20 to 31 percent.[1] The average, 26.75 percent, was used to calculate the improved delay based on the existing delay.

Projects that used adaptive signal control delays had an even greater delay reduction. From a U.S. Department of Transportation study, ATMS reduced delay between 19 to 44 percent[2]. The average, 31.5 percent, was used to calculate the improved delay based on the existing delay.

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[1] The reported range comes from the following three documents. The Kimley-Horn document has an average delay reduction of 29% in the Perimeter area of Atlanta, GA; Miami Dade shows a 20% average delay reduction; and the NTOC report references two case studies with non-automated ATMS technologies (a delay reduction of 31% and 27%).
Kimley-Horn and Associates, Inc. (2013). Perimeter Traffic Operations Program: Executive Summary. Accessed at
http://jkheneghan.com/city/meetings/2013/Sep/09092013_Perimeter_Traffic_Operations_Program.pdf
Public Works and Waste Management. (2013). Benefits of Advanced Traffic Management System. Miami-Dade County. Accessed at http://www.miamidade.gov/publicworks/benefits.asp
National Transportation Operations Coalition (NTOC). (2007). National Traffic Signal Report Card: Technical Report. Accessed at http://www.ite.org/reportcard/2007/technical_report_final.pdf

[2] Sussman, J. et al. (2000). What Have We Learned About ITS? *Federal High Administration, U.S. Department of Transportation.* Accessed at:
http://www.itsbenefits.its.dot.gov/its/benecost.nsf/0/B56A52DA1C256C8E8525725F00691912.

These delay reductions were used along with idle emission rates to estimate the emission reductions for ATMS projects.

2.2   Signal Synchronization

Project Types

This approach evaluates the emissions benefits of synchronizing traffic signals to enable vehicles to encounter multiple green lights (i.e., green wave) when traveling at a reasonable speed along a corridor. Previously, travel time savings at each intersection were calculated and aggregated using a delay reduction factor. In the updated approach, these calculations have been eliminated. Instead, travel time savings are set as direct inputs, allowing engineers to extract travel time results directly from the traffic capacity analysis software.

Methodology Limitations

This method specifically evaluates signal synchronization along an arterial corridor and cannot estimate systemwide or areawide improvements. However, areawide improvements can be estimated by testing individual corridors separately and summing their unique impacts. The length of the corridors and the signals being improved for synchronization should be reasonably spaced to achieve a meaningful reduction in travel savings. For example, travel time savings will be minimal for two signals spaced a mile apart compared to seven signals in a one-mile corridor.

This method assumes that all travel time savings benefits will be realized during the morning and afternoon weekday peak periods. Alterations to the strategy are required to consider travel time savings outside the morning and afternoon weekday peak periods. Also, the signal synchronization strategy is set up for a corridor with a pattern of high morning inbound traffic and high afternoon outbound traffic. Alternations to the strategy would be required to consider a corridor with comparable traffic in both directions.

User-Defined Inputs

The methodology requires a set of project-specific, user-defined inputs, as presented in Table 2.3. Two columns of inputs are needed: one for the peak direction during the morning peak and one for the peak direction during the evening peak.

The previous method required various inputs, such as the existing number of signalized intersections, number of lanes (one direction), average hourly volume during peak periods, and average cycle length (seconds), to calculate travel time savings based on HCM methods. These inputs are eliminated in the updated approach. Travel times before and after improvements are set directly as inputs, allowing engineers to obtain these values from traffic capacity analysis software (e.g., Synchro, SIDRA) and populate the input fields accordingly. This process allows more accurate travel time estimation and reduces the limitations and cumbersome steps in the old tool.

Table 2.3   Signal Synchronization Project User-Defined Inputs

User-Defined Input	Default Values	Input Guidance
Scenario Year		• Select a year between 2025 and 2035. The calculator cannot handle years outside this range. <mark>Please enter the anticipated year of letting.</mark>
Corridor Length (miles)		• Enter length of corridor targeted for signal synchronization
Average Traffic Volume during Peak Hour (one direction)		• Enter the average hourly volume over the multi-hour peak period and over all segments in the corridor. <mark>Please use values for the year of application</mark>.
Percentage of Trucks (one direction)		• Enter the average truck percentage for each direction during the peak period over all segments in the corridor. <mark>Please use values for the year of application</mark>.
Average Corridor Travel Time (min) during Peak Hour (peak direction) - before Improvements		• Enter time it takes for a vehicle to travel the length of the corridor in each direction during the peak period, before improvements. <mark>Please use values for the year of application</mark>.
Average Corridor Travel Time (min) during Peak Hour (peak direction) - after Improvements		• Enter time it takes for a vehicle to travel the length of the corridor in each direction during the peak period, after improvements. <mark>Please use values for the year of application</mark>.

Methodology

The updated methodology removes reliance on the California Department of Transportation's Traffic Light Synchronization Program (TLSP) delay calculation algorithms and the Highway Capacity Manual (HCM) 2000 delay equations. In this approach, travel times before and after improvements are set directly as inputs for the corridor's peak travel direction during the morning and afternoon peak periods.

From these inputs, average speeds before and after improvements are calculated for the defined corridor. These speeds are then matched to the corresponding emission rates from the MOVES emission rate tables. The emission rates before and after improvement are multiplied by the corridor's vehicle miles traveled (VMT) to determine the total emissions for each condition. The difference between the two totals (before vs. after) represents the net change in emissions attributable to the project.

By eliminating HCM-based calculations and intersection-level delay estimation, the new approach streamlines the process, improves flexibility for various project types, and allows results to be generated directly from measured or modeled travel times.

2.3   Intersection/Roundabout Improvement

Project Types

The previously defined improvements consider four types of intersection enhancements and one roundabout improvement, as outlined below:

- TYPE A (previous Section 2.3a) – New Signal – An unsignalized intersection approaching failure due to intolerable levels of delays is improved to a signalized intersection with an acceptable level of service.

- TYPE B (previous Section 2.3b) – New Phase – Enabling a specific turn or movement at the intersection that was nonexistent or making a permissive turn into a protected turn by changing the signal phasing and/or timing.

- TYPE C (previous Section 2.3c) – Capacity and Phase – Changes to the signalized intersection positively impacting level of service including improvements to geometry, approach redesign, or increased capacity. s

- TYPE D (previous Section 2.3d) – New Signal with Turn Lane – An unsignalized intersection improved to a signalized intersection due to long delays or insupportable traffic volumes with an addition of turn lanes.

- Roundabout (previous Section 2.4) - Constructing a roundabout at either an unsignalized or signalized intersection.

In the previous approach, the average delay reduction per vehicle for each improvement type was estimated using HCM-based methods and then aggregated to determine the total delay reduction, which was used to calculate emission reduction benefits.

In the updated approach, the process of delay estimation is simplified – total delay reduction values are set directly as inputs, allowing engineers to use results directly from traffic analysis software without additional intermediate calculations. In addition, all improvements at intersections (previous Section 2.3a-d and 2.4) have been consolidated into a new single Section 2.3 in the updated spreadsheet tool.

Methodology Limitations

The previous methodology estimated delay at the individual intersection level and was not designed to evaluate benefits across multiple intersections or at a systemwide scale. It relied on observed intersection delay studies when available, or on approximate delays derived from Level of Service (LOS) thresholds in the HCM. This introduced uncertainty due to the broad

delay ranges within each LOS category and was not well-suited for complex or staggered intersections. Similarly, the previous roundabout improvement method did not fully account for geometric design elements—such as size, shape, and layout—which can significantly influence vehicle delay.

The updated methodology reduces these limitations by using a more flexible input system where delay reduction values can be calculated separately using professional traffic analysis software (e.g., Synchro, SIDRA). This streamlined approach improves usability, accommodates a wider range of intersection and roundabout configurations, and better reflects site-specific conditions. However, like the previous method, it still focuses on individual intersections/roundabouts and is not intended for corridor-level or network-wide assessments. Accuracy remains dependent on the quality of input data.

User-Defined Inputs

The intersection/roundabout project approaches require the set of project-specific, user-defined inputs presented in Table 2.4.

Table 2.4   Intersection/Roundabout Improvement Project User-Defined Inputs

User-Defined Input	Default Values	Input Guidance
Scenario Year		Select a year between 2025 and 2035. The calculator cannot handle years outside this range. Please enter the anticipated year of letting.
Percentage of Trucks (Volume-Weighted Average Across All Directions)		Enter the percentage of trucks as a volume-weighted average across all travel directions for the intersection or roundabout. Please use values for the year of application.
Total Vehicle Second Delay (Veh-sec) in Peak Hour - before Improvements		Enter the total vehicle seconds of delay during the peak hour, before improvements. Please use values for the year of application.
Total Vehicle Second Delay (Veh-sec) in Peak Hour - after Improvements		Enter the total vehicle seconds of delay during the peak hour, after improvements. Please use values for the year of application.

Methodology

The total change in vehicle seconds of delay at the intersection/roundabout, before and after the improvement, is calculated as follows:

$$\Delta D_{int} = D_{intnb} - D_{intb}$$

Where:

D_{intnb} = Total delay at the intersection/roundabout for the no-build condition (before); and

D_{intb} = Total delay at the intersection/roundabout for the build condition (after).

The change in delay (ΔD_{int}) divided by 3600 represents the total reduction in vehicle hours of idling attributable to the improvement. This value is then multiplied by the applicable idle emissions factor (g/hr) for each pollutant and vehicle type, obtained from the MOVES emission rate database, to calculate the corresponding reduction in grams of emissions.

3.0 Transit Start-Up Operations and Expansion

3.1 New Transit Service and/or Transit Technology

Project Types

Transit expansion projects, such as new or extended bus routes, can cause shifts from auto travel, resulting in reductions in VMT and thus reductions in emissions. This methodology also estimates the emission reduction benefits of real-time transit arrival information by estimating additional ridership due to shorter wait associated with having this arrival information. Increased frequency of service (or reducing headways) and fleet expansions could also be modeled using the "percent of travel time spent waiting" constants associated with the real-time arrival information calculations.

Methodology Limitations

Some transit improvements, such as general enhancement of transit amenities (stops, sidewalks, benches); transit signal priority; queue jumper lanes; or bus rapid transit (BRT) are beyond the scope of this strategy.

The methodology for estimating the reduction in VMT due to real-time information assumes the previous service did not have real-time arrival information. Other service improvements, such as higher frequency or new routes, may not experience additional benefits due to real-time information already being available. Caution is advised for applying this methodology in this situation.

The simplifying assumption is made that paratransit shuttle buses have the same emission factors as passenger trucks (MOVES source type 31) since they actually are in EPA regulatory class LHD<=10K and LHD<=14K, which are small subsets of MOVES source type 31. If more exact emission rates are desired additional MOVES2014 runs could be conducted to extract emission rates by regulatory class instead of MOVES source type.

The methodology limits transit vehicle emission rates to the MOVES default mixes of diesel and CNG. Specific vehicle technology/fuels combinations, such as diesel, CNG, diesel hybrid-electric, battery electric, fuel cell electric, and plug-in hybrid, cannot be entered even if they

are known. If more detailed emission rates by technology/fuel combinations are desired they may be able to be derived from the Georgia Tech Fuel and Emissions Calculator for Transit Fleets.

User-Defined Inputs

The methodology requires the set of project-specific, user-defined inputs presented in Table 3.1.

Table 3.1   Transit Expansion Project User-Defined Inputs

User-Defined Input	Default Values	Input Guidance
Scenario Year		• Select a year between 2025 and 2035. The calculator cannot handle years outside this range. <mark>Please enter the anticipated year of letting.</mark>
Type of Bus		• Select the type of bus that will be used for the new/expanded transit service • Full size transit buses or smaller paratransit/shuttle buses are available
Average Daily Headways (minutes, per period)	15 minutes	• Enter average daily headways (minutes) of the new transit service by the AM Peak, PM Peak, and Off-Peak Periods • Default value of 15 minute headways represents a mid-level value for typical transit service frequencies
Length of Periods		• Enter the length of each period in hours • It is not required that all hours add to 24, some services are not available for a full day. However, the sum of all hours should not exceed 24.
Transit Corridor Length (miles)		• Enter the length of the transit corridor / route.
Does project include real-time arrival information?		• Select "Y" if project involves real-time arrival information
Daily Transit Ridership		• Enter average daily transit ridership added due to improvements

Methodology

The ridership for the new transit project must be estimated separately and input into the calculator. Once the ridership of the new service is known, it is used to calculate the VMT reduction. The equation to calculate decrease in light-duty VMT is as follows:

$$VMT = \frac{(R)}{AVO} \times TL$$

Where:

VMT = Reduction in daily light-duty VMT;

R = Ridership associated with new transit service;

AVO = Average passenger vehicle occupancy; and

TL = Average passenger vehicle trip length.

The VMT reduction is multiplied by the light duty emission factors to calculate emission reductions from fewer light duty vehicle trips. The added emissions from transit vehicles are calculated by multiplying the VMT for buses (number of buses per day times round trip route length) by the appropriate emission factor for either full size transit buses or smaller paratransit/shuttle buses. The total emissions reduction is calculated as the emissions reduced from light duty vehicles (including impact of real time arrival information) minus the transit vehicle emissions. To account for emissions associated with starting a vehicle, start vehicle emission rates are also considered. This is calculated by multiplying the total number of eliminated annual automobile trips (total ridership divided by the average automobile occupancy [1.2]) by the start emission rate factors and is added onto the emissions associated with a traveling vehicle.

Additional Ridership Due to Real-Time Arrival Information

The reduction in single-occupant vehicle emissions is the driving force behind estimating how real-time information will improve air quality. The methodology is based on an increase in transit ridership due to a decrease in wait time for the bus.

According to the 2001 National Household Travel Survey, approximately 26 percent of the total travel time while riding transit is spent waiting[3]. The implementation of real-time information allows users to know exactly when the next bus is arriving at their stop. This reduces the user's wait time for the bus by removing the need to arrive early in case the bus is running ahead of schedule. It also allows riders to utilize their time more efficiently in case the bus is running late. A recent study found that riders who use real-time information wait almost two minutes less than those who use traditional schedule information[4]. This decrease results in approximately 21 percent of total travel time spent waiting when real-time information is available.

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[3] National Center for Transit Research (2005). *Public Transit in America: Results from the 2001 National Household Travel Survey*. Accessed from: http://www.nctr.usf.edu/pdf/527-09.pdf.

[4] Watkins, K. E., Ferris, B., Borning, A., Rutherford, G. S., Layton, D. (2011). Where Is My Bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders. *Transportation Research Part A: Policy and Practice 45*(8) 839-848.

Using this decrease in total time spent waiting, a travel wait time elasticity of -0.54 is applied to predict the increase in transit ridership due to this new technology[5]. This reduces the number of annual single-occupant vehicle trips, in turn, reducing the total annual emissions.

Also, a second source estimated the direct effects of real-time information on transit ridership. This study concluded that, when all other variables are controlled, there is a ridership increase of approximately 2 percent when real-time information is introduced to transit service.[6] This 2 percent increase was applied to the user-inputted/calculated transit ridership and compared to the previously discussed wait time methodology. The results were very comparable, with ridership estimates different by less than 0.2 percent. In the calculator, estimating the increase in ridership is based on the wait time methodology.

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[5] Iseki, H., Taylor, B. D., Miller, M. (2006). The Effects of Out-of-Vehicle Time on Travel Behavior: Implications for Transit Transfers. *Tool Development to Evaluate the Performance of Intermodal Connectivity (EPIC) to Improve Public Transportation.* Access at http://www.its.ucla.edu/wp-content/uploads/sites/6/2014/06/Appendix-A.pdf.

[6] Tang, L., Thakuriah, P. V. (2012). Ridership effects of real-time bus information system: A case study in the City of Chicago. *Transportation Research Part C 22*(2012) 146-161. Accessed from http://foresight.ifmo.ru/ict/shared/files/201311/1_149.pdf.

4.0 Travel Demand Management

4.1 Bike/Pedestrian and Transit

Project Types

This approach evaluates bike and pedestrian infrastructure improvements that are parallel to an arterial roadway with known average daily traffic (ADT) volumes. The benefits of increased transit ridership are included for bike and pedestrian projects that provide increased accessibility to transit. Projects can be evaluated individually for bike or pedestrian facilities, or combined.

Pedestrian and bicycle facilities can reduce emissions when auto trips are replaced by walking, biking, and transit trips. The methodology estimates the annual number of vehicle trips reduced, and the annual auto VMT reduced to approximate the emissions reduction.

Methodology Limitations

The approach does not completely account for all elements of pedestrian bridges or multiuse facilities/greenways in exclusive ROW; however, the regional bike/pedestrian project strategy, which is based on total travel demand between an origin and destination, can be used instead.

The approach does not test potential mode shifts to nonmotorized and transit modes as a result of complete street elements (e.g., benches, lighting, improved buffers); traffic-calming strategies; transit station design elements, such as a bike station; employer-based strategies (e.g., bike lockers, showers); or improved transit amenities.

User-Defined Inputs

The methodology requires the set of project-specific, user-defined inputs presented in Table 4.1.

Table 4.1   Bike/Pedestrian and Transit Project User-Defined Inputs

User-Defined Input	Default Values	Input Guidance
Scenario Year		• Select a year between 2025 and 2035. The calculator cannot handle years outside this range. Please enter the anticipated year of letting or initial year of program.
AADT on the parallel arterial		• Enter annual average daily passenger vehicle traffic on nearest parallel roadway. • Enter the sum of volumes in both directions for the entire day • If the average weekday traffic (ADT) is known instead, multiply by 0.93 to get AADT
Capacity of parallel arterial (vph)		• Enter the capacity of all lanes in both directions of the parallel arterial in vehicles/hour • Single lane values can be looked up at the top of the other variables tab (based on area type and facility type) and multiplied by the number of lanes in both directions
Length of project (miles)		• Enter total length of the bike/pedestrian project.
Posted Speed on parallel arterial (mph)		• Enter the speed limit in miles per hour on the parallel arterial • This speed is used to calculate free-flow travel time.
Number of activity centers within ½ mile of bicycle project		• Select appropriate number of activity centers. • Activity center examples include banks, churches, hospitals, park-and-ride, office parks, library, shopping, and schools.
Number of activity centers within ¼ mile of pedestrian project		• Select appropriate number of activity centers • Activity center examples include banks, churches, hospitals, park-and-ride, office parks, library, shopping, and schools
Within 2 miles of a university or college (Y/N)?		• Select "Y" if any segment of project is within 2 miles of a university or college.
Area type		• Select from CBD, Urban, Suburban, Mountain, and Rural area types.
Does this project have a bicycle component?		• Enter "Y" if the project provides bicycle infrastructure; otherwise enter "N."
Average length of bicycle trips (miles)	1.8	• Enter estimated average length of bicycle trips in the area; leave blank if a pedestrian project only. • Default value (1.8 mi) is based on 2001 NHTS statistics, excluding purely recreational trips.

User-Defined Input	Default Values	Input Guidance
Does this project have a pedestrian component?		• Enter "Y" if the project provides pedestrian infrastructure; otherwise enter "N."
Average length of pedestrian trips (miles)	0.5	• Enter estimated average length of pedestrian trips in the area; leave blank if bike project only. • Default value (0.5 mi) is based on 2001 NHTS statistics, excluding purely recreational trips
Does project provide direct access to transit?		• Answer "Y" if any segment of project provides direct access to transit (station or bus stop).
Average length of transit trips (miles)	5.2	• Enter estimated average length of transit trips in the area. • Default value based on the American Public Transportation Association (APTA) 2009 Factbook,[7] Table 7 (Bus = 3.9 mi; Commuter Rail = 24.3 mi; Heavy Rail = 4.7 mi; Average = 5.2 mi).
Existing daily transit boardings		• Enter estimated total weekday boardings for all transit access points along project corridor.
Provides access to fixed guideway transit?		• Select "Y" if the segment provides direct access to fixed guideway transit.

Methodology

The bike project approach is consistent with *Methods to Find the Cost-Effectiveness of Funding Air Quality Projects*, a handbook prepared by the CARB in 2005. The CARB handbook describes how to evaluate Motor Vehicle Registration Fee Projects and Congestion Mitigation and Air Quality Improvement (CMAQ) projects, and is the basis for determining the amount of emissions reductions from bicycle facility projects.

The 2009 report *Methodologies for Evaluating Congestion Mitigation and Air Quality Improvement Projects*, developed for the Maricopa Association of Governments (MAG), is the basis for determining emissions reductions resulting from auto trips replaced by pedestrian trips. The MAG document adapted the methodology for calculating the impact of pedestrian improvements from the 2005 CARB handbook.

The approaches for bike and pedestrian projects are consistent. Within the general CARB approach, two primary factors drive the calculation of reduced auto trips: 1) the number of

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[7] APTA (2009), *Public Transportation Factbook, 60th Edition,* American Public Transportation Association, accessed at http://www.apta.com/gap/policyresearch/Documents/APTA_2009_Fact_Book.pdf.

activity centers adjacent to the project, and 2) the project location with respect to a nearby university or college.[8]

The number of activity centers within one-quarter mile of a pedestrian project and one-half mile of a bike project feed into a lookup table of factors generating percent auto trip reductions. The university/college location factor increases average trip lengths on the assumption that willingness to bike or walk, and the average distances for these trips are greater for college students.

Calculations for auto trips reduced as a result of increased bike and pedestrian trips generated by the project are listed below.

$$\text{Daily auto trips reduced }_{(bike)} = AADT * (C_{\frac{1}{2}\text{ mile}} + A)$$

$$\text{Daily auto trips reduced }_{(walk)} = AADT * (C_{\frac{1}{4}\text{ mile}} + A)$$

Where:

AADT = Annual average daily traffic on the adjacent or nearest parallel arterial;

$C_{\frac{1}{2}\text{ mile}}$ = Activity center credit for centers with ½ mile

$C_{\frac{1}{2}\text{ mile}}$ = Activity center credit for centers with ¼ mile

A = Adjustment factor for AADT

The additional transit access element within this project approach is addressed through a lookup table quantifying the increase in transit trips, based on type of access and area type (two percent for improved access to bus; four percent for improved access to fixed guideway).

The source for increases in transit trips is the Transit Cooperative Research Program (TCRP) Report 95, *Traveler Response to Transportation System Changes, Chapter 17 – Transit-Oriented Development (TOD)*, which summarizes travel mode shifts of residents upon relocation into TODs. The TCRP report specifically references California results based upon a

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[8] Per CARB documentation, adjustment factors were derived from a limited set of bicycle commute mode split data for cities and university towns in the southern and western United States (Source: U.S. DOT (1992), *National Bicycling And Walking Study – Transportation Choices for a Changing America*). This data was then averaged and multiplied by 0.7 to estimate potential auto travel diverted to bikes. On average, about 70 percent of all person trips are taken by auto driving (Source: Caltrans (2002), *2000-2001 California Statewide Travel Survey*), and it is these trips that can be considered as possible auto trips reduced. Finally, this number was multiplied by 0.65 to estimate the growth in bicycle trips from construction of the bike facility. Sixty-five percent represent the average growth in bike trips from a new bike facility, as observed in before and after data for bike projects (Source: U.S. DOT (1994), *A Compendium of Available Bicycle and Pedestrian Trip Generation Data in the United States*). Benefits are scaled to reflect differences in project structure, length, traffic intensity, community size, and proximity of activity centers. The scale has been adapted from a method developed by Dave Burch of the Bay Area Air Quality Management District (BAAQMD).

2003 study by Lund, Cervero, and Willson.[9] The shift to transit was larger for residents along the Bay Area Rapid Transit District (BART) heavy-rail system (4.2 percent) than for TOD survey respondents statewide (1.8 percent). These results indicated a reasonable estimate for percent increases as a result of improved accessibility: two percent for bus trips and four percent for fixed guideway trips. Results from the *TCRP Report 95* sources are assumed to approximate responses in high-density areas with population densities over 5,000 people per square mile. Increase percentages in areas with lower densities are based on VMT per capita relationships by population density from the 2001 NHTS (see **Error! Reference source not found.**). This relationship was applied to the Indianapolis MPO's definition of area type to interpolate the annual VMT per capita and calculate a relevant percentage increase in transit trips (see Table 4.3 and Table 4.4).

Table 4.2   VMT per Capita by Area Type as Defined by NHTS

Area Type	Population Density People per Square Mile (ppsm)	Annual VMT Per Capita
Difficult Terrain/Rural	0 – 499	11,818
Suburban	500 -1,999	10,435
Urban	2,000 – 3,999	9,678
Urban	4,000 – 9,999	8,285
CBD/Core	10,000+	4,639

Source: NHTS, 2001.

Table 4.3   Estimated VMT per Capita by Area Type in Indianapolis Area

Area Type	Population Density People per Square Mile (ppsm)	Interpolated Annual VMT Per Capita
CBD	2,800	9,756
CBD Fringe	2,800	9,765
Residential	1,350	10,390
Suburban CBD	2,875	9,732
Rural	120	11,818

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[9] H. Lund, R. Cervero, and R. Willson (2003), *Travel Characteristics of Transit-Oriented Development in California*, accessed at: http://www.csupomona.edu/~rwwillson/tod/Pictures/TOD2.pdf.

Table 4.4   Increase in Transit Trips by Area Type and Transit Mode

Area Type	Bus	Fixed Guideway
CBD	1.7%	3.4%
CBD Fringe	1.7%	3.4%
Residential	1.6%	3.2%
Suburban CBD	1.7%	3.4%
Rural	1.4%	2.8%

Source: NHTS, 2001.

The calculation for auto trips reduced by new transit trips is detailed below.

$$\text{Daily auto trips reduced}_{\text{(transit)}} = B_{\text{(project corridor)}} * I_{\text{(area type \& mode)}}$$

Where:

B = Daily transit boarding for all transit access points along bike/pedestrian project corridor; and

I = Percent increase in transit trips as presented in Table 4.4**Error! Reference source not found.**.

Auto trips reduced by bike, walk, and transit modes are translated into VMT based on average bike, walk, and transit trip lengths. The methodology uses default average trip lengths based on the NHTS and APTA *2009 Factbook* data, but can be replaced with user-defined, local-specific data. The VMT reductions annualized (assumes a factor of 200 days, since commute benefits are assumed only to accrue during workdays and to account for local climate) and summed together. The small increase in congested speed due to slightly lower volumes is calculated using the BPR equation as explained in the Managed Lanes section. Emission rates before and after the project are looked up based on the calculated speeds and multiplied by VMT before and after the project to calculate emissions. The emission reduction is calculated by subtracting the "after project" emissions from the "before project" emissions. In addition, because these projects affect VMT due to a decrease in the number of automobile trips, emissions formed through starting a vehicle are also considered. This is calculated by multiplying the total number of automobile trips reduced by the start vehicle emission rate before being added to the previously calculated emission reduction.

4.2 Regional Bike/Pedestrian Projects

Project Types

This approach evaluates regionally significant bike and/or pedestrian infrastructure projects that are on a separated facility, not necessarily directly adjacent to a roadway. Potential emissions reductions result from the decrease in emissions associated with auto trips being replaced by bicycle and/or pedestrian trips. Projects can be evaluated singularly by mode or combined. The user specifies the average length of the bike and pedestrian trips on the corridor, and the number of activity centers along the corridor for each mode. If the project will only positively impact one mode (for example, a bicycle trail), then the user specifies inputs for that specific mode only. If the project implements both pedestrian and bike improvements (e.g., a multiuse path or trail), the user may input values for each mode.

Methodology Limitations

The approach does not test potential mode shifts to nonmotorized modes as a result of complete street elements (e.g., benches, lighting, improved buffers); traffic calming strategies; or employer-based support strategies (e.g., bike lockers, showers).

User-Defined Inputs

The methodology requires the set of project-specific, user-defined inputs presented in Table 4.5.

Table 4.5   Bike/Pedestrian Project User-Defined Inputs

User-Defined Input	Default Values	Input Guidance
Scenario Year		• Select a year between 2025 and 2035. The calculator cannot handle years outside this range. Please enter the anticipated year of letting or initial year of program..
AADT between origin and destination of route		• Use results from travel demand model origin/destination data
		• Alternatively, enter average weekday passenger vehicle traffic on parallel roadway with generally the same origin and destination
		• If average weekday traffic (ADT) is known instead, multiply by 0.93 to get AADT

User-Defined Input	Default Values	Input Guidance
Capacity of parallel arterial (vph)		• Enter the capacity of all lanes in both directions of the parallel arterial in vehicles/hour • Single lane values can be looked up at the top of the other variables tab (based on area type and facility type) and multiplied by the number of lanes in both directions
Posted Speed on parallel arterial (mph)		• Enter the speed limit in miles per hour on the parallel arterial • This speed is used to calculate free-flow travel time.
Number of activity centers within ½ mile of bicycle project		• Select appropriate number of activity centers. • Activity center examples include banks, churches, hospitals, park-and-ride, office parks, library, shopping, and schools; credit is only given for 3 or more centers
Number of activity centers within ¼ mile of pedestrian project		• Select appropriate number of activity centers. • Activity center examples include banks, churches, hospitals, park-and-ride, office parks, library, shopping, and schools; credit is only given for 3 or more centers
Within 2 miles of a university or college (Y/N)?		• Select "Y" if any segment of project is within 2 miles of a university or college.
Area type		• Select from CBD, Urban, Suburban, Mountain, and Rural area types.
Predicted Total Daily Bicycle Demand (optional input to use in place of first six inputs)		• Enter the estimated number of daily bicycle trips along the facility, if known
Predicted Total Daily Pedestrian Demand (optional input to use in place of first six inputs)		• Enter the estimated number of daily pedestrian trips along the facility, if known
Does this project have a bicycle component?		• Enter "Y" if the project provides bicycle infrastructure; otherwise enter "N."
Does this project have a bicycle component?		• Enter "Y" if the project provides bicycle infrastructure; otherwise enter "N."
Average length of bicycle trips (miles)	1.8	• Enter estimated average length of bicycle trips in the area; leave blank if a pedestrian project only. • Default value (1.8 mi) is based on 2001 NHTS statistics, excluding purely recreational trips.
Does this project have a pedestrian component?		• Enter "Y" if the project provides pedestrian infrastructure; otherwise enter "N."

User-Defined Input	Default Values	Input Guidance
Average length of pedestrian trips (miles)	0.5	• Enter estimated average length of pedestrian trips in the area; leave blank if bike project only. • Default value (0.5 mi) is based on 2001 NHTS statistics, excluding purely recreational trips
Length of bike/ped project (miles)		• Enter total length of the bike/pedestrian project

Methodology

The bike project approach is consistent with *Methods to Find the Cost-Effectiveness of Funding Air Quality Projects*, a handbook prepared by the CARB in 2005. The CARB handbook describes how to evaluate Motor Vehicle Registration Fee Projects and Congestion Mitigation and Air Quality Improvement (CMAQ) projects, and is the basis for determining the amount of emissions reductions from bicycle facility projects.

The 2009 report *Methodologies for Evaluating Congestion Mitigation and Air Quality Improvement Projects*, developed for the Maricopa Association of Governments (MAG), is the basis for determining emissions reductions resulting from auto trips replaced by pedestrian trips. The MAG document adapted the methodology for calculating the impact of pedestrian improvements from the 2005 CARB handbook.

The approaches for bike and pedestrian projects are consistent. Within the general CARB approach, two primary factors drive the calculation of reduced auto trips: 1) the number of activity centers adjacent to the project, and 2) the project location with respect to a nearby university or college.[10]

The number of activity centers within one-quarter mile of a pedestrian project and one-half mile of a bike project feed into a lookup table of factors generating percent auto trip reductions. The university/college location factor increases average trip lengths on the assumption that willingness to bike or walk, and the average distances for these trips are greater for college students.

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[10]Per CARB documentation, adjustment factors were derived from a limited set of bicycle commute mode split data for cities and university towns in the southern and western United States (Source: U.S. DOT (1992), *National Bicycling And Walking Study – Transportation Choices for a Changing America*). This data was then averaged and multiplied by 0.7 to estimate potential auto travel diverted to bikes. On average, about 70 percent of all person trips are taken by auto driving (Source: Caltrans (2002), *2000-2001 California Statewide Travel Survey*), and it is these trips that can be considered as possible auto trips reduced. Finally, this number was multiplied by 0.65 to estimate the growth in bicycle trips from construction of the bike facility. Sixty-five percent represent the average growth in bike trips from a new bike facility, as observed in before and after data for bike projects (Source: U.S. DOT (1994), *A Compendium of Available Bicycle and Pedestrian Trip Generation Data in the United States*). Benefits are scaled to reflect differences in project structure, length, traffic intensity, community size, and proximity of activity centers. The scale has been adapted from a method developed by Dave Burch of the Bay Area Air Quality Management District (BAAQMD).

Calculations for auto trips reduced as a result of increased bike and pedestrian trips generated by the project are listed below.

$$\text{Daily auto trips reduced }_{(bike)} = AADT * (C_{\frac{1}{2}\text{ mile}} + A)$$

$$\text{Daily auto trips reduced }_{(walk)} = AADT * (C_{\frac{1}{4}\text{ mile}} + A)$$

Where:

AADT = Annual average daily traffic on the adjacent or nearest parallel arterial;

$C_{\frac{1}{2}\text{ mile}}$ = Activity center credit for centers with ½ mile

$C_{\frac{1}{2}\text{ mile}}$ = Activity center credit for centers with ¼ mile

A = Adjustment factor for AADT

If the average daily vehicular traffic between the origin and destination is not known or does not accurately represent the vehicular path that would be taken if the project was not developed, then a predicted total daily bicycle and pedestrian demand for the facility must be known. This prediction may include commuting and non-commuting trips. From the *2012 National Survey of Bicyclist and Pedestrian Attitudes and Behaviors*, approximately 11 percent of bicycle trips and 8 percent of pedestrian trips are for commuting purposes. The inputted daily demand is then multiplied by these percentages to predict the number of automobile trips reduced due to the regionally significant bicycle and pedestrian facility This value may be adjusted under the 'Constants' section or put to 100 percent if the predicted total daily demand includes only commuters.

Auto trips reduced by biking and walking modes are translated into VMT based on average bike and walk trip lengths. Default average trip lengths based on the NHTS shown in Table 4.5 can be used or replaced with user-defined, local-specific data. The VMT reductions annualized (assumes a factor of 200 days, since commute benefits are assumed only to accrue during workdays and to account for local climate) and summed together. The small increase in congested speed due to slightly lower volumes is calculated using the BPR equation as explained in the Managed Lanes section. Emission rates before and after the project are looked up based on the calculated speeds and multiplied by VMT before and after the project to calculate emissions. The emission reduction is calculated by subtracting the "after project" emissions from the "before project" emissions. Similar to the previous strategy, the emissions associated with starting a vehicle are also considered. This is calculated by multiplying the total number of automobile trips reduced by the start vehicle emission rate before being added to the previously calculated emission reduction.

4.3   Carpooling / Vanpooling Strategies

Project Types

This approach evaluates the emission benefits of developing a carpool / vanpool or similar rideshare program. Projects under this category can include region-wide programs that assist commuters with finding carpools and vanpools, employer-based programs that provide ridesharing options to its employees, or any similar type of project. These projects should display evidence or an estimation of the number of users switching to carpooling or vanpooling as their commute mode. This decreases the number of daily vehicles on the roadway, reducing the annual vehicle miles traveled, which results in fewer emissions.

Methodology Limitations

Many rideshare programs have components to provide commuters tools to find and create carpools and vanpools. These are usually available through an online website and can track the total benefits achieved through the alternative transportation mode. This calculator does not predict the effect these programs have on the number of users.

Other components that can vary between ridesharing programs, such as cost, location of origin and destination, or qualifications, are also not considered in this calculation. While these factors may affect the number of users, the impact these components have on participation are not estimated.

User-Defined Inputs

The methodology requires the set of project-specific, user-defined inputs presented in Table 4.6.

Table 4.6   Carpool/Vanpool Project User-Defined Inputs

User-Defined Input	Default Values	Input Guidance
Scenario Year		• Select a year between 2025 and 2035. The calculator cannot handle years outside this range. Please enter the anticipated year of letting or initial year of program.
Number of Carpools / Vanpools		• Enter the total number of carpools and vanpools in the program. • Should represent the total number of routes. • If two vehicles are used for the same route, this would equal two different carpools / vanpools.
Average Length of Trip (miles)		• Enter the average length of a one-way trip • Model assumes morning commute is the same length as the evening commute. If lengths are different, use the average of the morning and evening trip.
Average Number of Passenger per Carpool / Vanpool		• Enter the approximate number of passengers per vehicle.

Methodology

The purpose of ride sharing is to provide an alternative transportation option to commuters and to reduce the number of vehicles on the road. By maximizing the number of occupants in a vehicle, the trip is more optimized and lowers the average emission output per person.

The calculation for predicting emission reduction for carpool/vanpool strategies is consistent with *Methods to Find the Cost-Effectiveness of Funding Air Quality Projects*, a handbook prepared by the CARB in 2005[11]. This approach considers the emission reductions accounting for three factors that influence VMT. This includes 1) a reduction due to replacing automobile trips with the carpool / vanpool 2) accounting for the increase in emissions due to the new, individual trips taken in order to access the rideshare and 3) the emission outputs by the carpool / vanpool vehicle itself.

The approaches for calculating the reduction in emissions is consistent with the CARB approach. However, unlike CARB, this methodology accounts for the VMT of the rideshare program itself. Overall, the calculation for VMT reduced is listed below:

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[11] California Environmental Protection Agency. (2005). *Methods to Find the Cost-Effectiveness of Funding Air Quality Projects: For Evaluating Motor Vehicle Registration Fee Projects and Congestion Mitigation and Air Quality Improvement (CMAQ) Projects.* California Department of Transportation (Caltrans). Accessed at: http://www.arb.ca.gov/planning/tsaq/eval/eval.htm

$$\text{Annual VMT Reduced} = [\ (AT * L\ ) - (PR * LL\ )\ ] - RV$$

Where:

AT = Annual Automobile Trips Reduced (assumes 1.2 people per vehicle before carpool/vanpool strategy),

L =Average Length of Trip (miles),

PR = Annual Automobile Trips to Park and Ride Lot (assumes 90% of AT),

LL = Average Trip Length for Auto Access to Rideshare (miles, one-way; assumes five miles, one-way); and,

RV = Annual Rideshare Vehicle VMT.

Various factors are considered in these calculations including accounting only the riders who previously drove to work and those who will drive to the park and ride lot. The CARB documentation provides default values for these factors.

In addition, because emissions differ between cars and vans, the reduction in VMT is calculated separately for a carpool and vanpool program. Emission factors for these specific vehicles are then applied to the reduction in VMT to estimate the total reduction in emissions. In addition, because these projects impact VMT due to a decrease in the number of automobile trips, emissions formed through starting a vehicle are also considered. This is calculated by multiplying the total number of automobile trips reduced by the start vehicle emission rate before being added to the previously calculated emission reduction. Riders who take an automobile trip to a park and ride location are not included in the start emission calculation. The starting vehicle emissions from the rideshare vehicles are also considered and subtracted from the total emission reductions.

5.0 Other Tabs in Calculator

5.1 Preparation of Running Emission Rates from MOVES

Running emission rates for 2025 and 2035 were developed using EPA's latest MOVES5 model at the county scale for Marion County, Indiana, under typical weekday conditions. These rates form the foundation for estimating emissions impacts in the CMAQ methodology. The finalized outputs are presented in the blue tables on the left-hand side of the "2025ER" and "2035ER" tabs, organized for direct reference in project calculations.

MOVES inputs were prepared using the most recent datasets provided by IMPO, ensuring consistency with current regional travel demand model assumptions and vehicle fleet characteristics. Key datasets included source type population, seasonal and annual meteorology, vehicle age distribution, average speed distribution, road type distribution, vehicle type VMT, and VMT fractions. For winter CO runs, MOVES5 default meteorological data was applied to reflect colder operating conditions.

Six MOVES scenarios were executed to capture both seasonal and pollutant-specific variations. Annual runs were performed for CO_2e, $PM_{2.5}$, NO_x, and SO_2; summer runs addressed ozone-related pollutants (NO_x and VOC); and winter runs were used for CO, which is sensitive to low temperatures. Each set of runs was performed for both 2025 and 2035, producing six distinct datasets: 2025 annual, summer, and winter, and 2035 annual, summer, and winter. This multi-run approach ensures that the emission rates reflect realistic seasonal differences in vehicle operation and pollutant formation.

Two categories of running emission rates were developed to accommodate different project evaluation needs. Speed-specific rates were generated using MOVES5 for each analysis year, excluding start-related emission processes (Process IDs 2 and 16) to focus solely on running emissions. VMT-based aggregation was applied using a weighted average method to remove unnecessary hourly detail and to consolidate MOVES source types into broader vehicle categories used in the CMAQ tool. Aggregation weights were derived from the MOVESOutput and MOVESActivityOutput tables, ensuring accurate representation of the regional traffic mix.

General running emission rates were developed for strategies where specific operating speeds are unknown, such as projects targeting overall VMT reduction across broad geographic areas. In this case, the average speed for each vehicle and road type was calculated from the speed distribution data and matched to the nearest rate in the speed-specific tables. Where calculated speeds fell between the standard 5 mph intervals used in MOVES, linear interpolation was applied to derive accurate rates.

All running emission rates are expressed in grams per mile. As a quality assurance measure, the new 2025 results were compared against previous 2015 and 2025 rates. The outputs were found to be consistent with previous data, confirming that the methodology, inputs, and aggregation procedures produce reliable and credible emission rates for use in CMAQ project evaluations.

5.2 Preparation of Idle Emission Rates from MOVES

Idle emission rates, expressed in grams per hour, are presented in the orange tables on the right-hand side of the "2025ER" and "2035ER" tabs. These rates are applied in calculating emission reductions for strategies that reduce vehicle delay.

MOVES input data for idle emission rate development was updated using the latest datasets provided by IMPO. These included source type population, summer and annual meteorology, age distribution, average speed distribution, road type distribution, vehicle type VMT, and VMT fractions. For winter CO runs, MOVES5 default meteorological data was used.

Following the guidance from EPA MOVES team, idle emission rates were derived directly from the same MOVES runs used to produce the speed-specific running emission rates. The idle emission rates were taken from off-network activity in MOVES outputs, because the grams/hour values for idling at traffic signals are equivalent to those for off-network idling.

To develop the rates, MOVES outputs for idle emissions were extracted, and a weighted aggregation was performed to combine multiple MOVES source types into broader vehicle categories. The aggregation weights were based on source type population data, ensuring the resulting idle emission rates reflect the composition of the vehicle fleet in Marion County for the 2025 and 2035 weekday scenarios. All idle emission rates are expressed in grams per hour.

For quality assurance, the 2025 idle emission rates were compared with those from previous 2015 and 2025 rates, and the results were found to be consistent, confirming the validity of the methodology and data inputs.

5.3 Other Variables

This tab contains a number of constants and other variables often applied in the strategy lookup tables.

5.4 Sources and Comments

This tab compiles sources and comments for all strategies associated with default values and other constants.