FINAL SUSTAINABLE COMMUNITIES STRATEGY

PROGRAM AND EVALUATION GUIDELINES

APPENDICES

NOVEMBER 2019

CALIFORNIA AIR RESOURCES BOARD

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Appendix A: Technical Methodology Submission Template and Guidance

This section proposes a standardized template for MPOs to use for a Technical Methodology submittal to CARB. The Technical Methodology is the first deliverable submitted to CARB by the MPO at the onset of the RTP/SCS development process before any public engagement and explains how the MPO will quantify GHG emission reductions in the RTP/SCS. The Technical Methodology is submitted to CARB for review and acceptance. It is a required piece of the SCS Evaluation Process under Government Code § 65080(b)(2)(J)(i). The following template was developed by CARB staff from previous Technical Methodology submissions, and reflects the new direction adopted by CARB through the 2018 GHG emission reduction target update process. The purpose of this template is to serve as a guide for MPOs and help improve consistency among MPOs and clearly state the information needed for CARB to accept an MPO's proposed methodology, thus minimizing the need for revisions to the Technical Methodology.

Cover Letter

A formal cover letter should be accompanied with each Technical Methodology submission that references Government Code § 65080(b)(2)(J)(i). The cover letter should include mention of the applicable travel demand models used, a brief description of the RTP/SCS, and a date of the submittal.

Technical Methodology

The Technical Methodology aggregates several steps an MPO follows to quantify GHG emission reductions from the RTP/SCS. CARB staff recommends MPOs include the following content in the Technical Methodology submission to CARB to minimize the need for revisions:

Title

Technical Methodology to Estimate Greenhouse Gas Emissions for the [insert date range of RTP/SCS] RTP/SCS from the [Insert full name of MPO]

Introduction

- Purpose of Technical Methodology: include reference to Government Code § 65080(b)(2)(J)(i)
- Applicable per capita GHG emission reduction targets set by CARB including past targets and past SCS GHG emission reduction achievement

Overview of analysis years, including year and purpose of modeling each specific year

Table 1 provides an <u>example</u> of analysis years considered in a MPO's RTP/SCS:

Table 1. Example Analysis Years Considered in MPO's RTP/SCS

Year	Purpose
2005	Base Year for SB 375 GHG emission reduction Target Setting
2010	Base Year for current RTP/SCS
2020	SB 375 GHG Emission Reduction Target
2035	SB 375 GHG Emission Reduction Target
2050	Current RTP/SCS Horizon Year

- Overview of the RTP/SCS schedule, including the start date of public process for MPO scenario development
- Significant or notable changes in the regional or local planning context (e.g., changes in projected revenue to the extent known and available; updates to local plans; annexations or significant project approvals; new information available [study results or available datasets]) since the prior RTP/SCS was adopted
- Identification of the recommendations CARB provided in the previous SCS evaluation and an explanation of how those recommendations have been incorporated into the new SCS or if they will be addressed at a future time.

Overview of Existing Conditions

- Notable changes to the existing regional or local planning contexts that are likely to influence the RTP/SCS development process
- Key issues in the region influencing RTP/SCS policy framework and discussions (e.g., housing, economic development, emerging technologies)

Population and Employment Growth Forecasts

- Updated regional growth forecast information, to the extent known and available (e.g., population, jobs, housing) compared to last RTP/SCS
- Explanation of any changes to the regional growth forecast methodology
- Discussion of how the regional growth forecast will be integrated into the MPO's land use model

Quantification Approaches

- Specify quantification approaches for each of the potential RTP/SCS strategies under consideration, to the extent known and available. **Table 2** provides examples of quantification approaches associated with potential RTP/SCS strategies.

Table 2. Example RTP/SCS Strategy Quantification Approaches

RTP/SCS Strategy	Quantification Approach
Targeted infill/increase density in transit priority areas	Travel Demand Model
New transit capital projects	Travel Demand Model
Bike and pedestrian infrastructure	Travel Demand Model
Regional express lane pricing	Travel Demand Model
Regional bike and car share programs	Off-Model
Telecommute programs	Off-Model
Additional infrastructure for electric vehicle charging	Off-Model

- Specify the assumptions and methods used to estimate interregional travel
- Specify version of CARB's mobile-source emission factor model that will be used for estimating GHG emissions (e.g., EMFAC2014) and mention of the version used in the previous RTP/SCS[1]

Land Use/Travel Demand Modeling

- Description of all updates or improvements made to land use and travel demand models
- Characterization of any new inputs or data sets used in the land use and travel demand models
- Commitments to provide model sensitivity tests for RTP/SCS strategies under consideration (see **Appendix B** for full list of potential sensitivity tests)
- Discussion of whether and how the travel model accounts for short- and long--term effects of induced demand for new roadway capacity projects[2]

List of Exogenous Variables and Assumptions for Use in Proposed RTP/SCS

- At this time, the MPO should commit to its assumptions, to the extent known and available, for independent (exogenous) variables (see **Table 3).** MPOs should list the exogenous variables that are inputs to the travel demand model and not part of the RTP/SCS scenario development process, and document those variables in the submittal.

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[1] For more information about the EMFAC model see appendix D (EMFAC adjustment Methodology).

[2] Tools are available to help MPOs evaluate the effects of induced travel. Examples include, but are not limited to; University of California, Davis National Center for Sustainable Transportation's Induced Travel Calculator, Available at: https://ncst.ucdavis.edu/research/tools/ and *Impact of Highway Capacity and Induced Travel on Passenger Vehicle Use and Greenhouse Gas Emissions*. October 2013. Available at: https://www.arb.ca.gov/cc/sb375/policies/hwycapacity/highway_capacity_brief.pdf.

- Specify the assumptions used to derive the cost of travel (i.e. auto operating cost). Auto Operating Cost is derived from the cost of fuel and non-fuel related costs (maintenance, repair, and tire wear).

Table 3. List of Exogenous Variables for Incremental Progress Analysis

Category of Variable (as applicable)	Variable Specification in Model[1]	Example Assumption in 2035
Demographics	Population, employment & housing	Population: 7 million Employment: 3 Million Housing: 2.5 Million
Auto operating cost	Fuel and non-fuel related costs (maintenance, repair, and tire wear)	22 cents/mile
Vehicle fleet efficiency	EMFAC model	Average fuel economy 36 mpg
Household income	Median or distribution	Median income - $63,000 per year
Share of TNC Trips, single and pooled	Number of trips by TNC for different trip purposes	HBW: 15% HBSh: 20% HBO: 10% NHB: 5%
Household demographics	Household size, workers, age	HH Size: 3.1 persons/HH Workers: 1.3 persons/HH
Commercial vehicle activity	Number of commercial vehicle trips	10% of regional VMT (external-external)
Interregional travel	Share of external interregional VMT	5% of regional VMT (external-external)
MPO travel demand model version		Trip-based or ABM Version X.x

[1] Comparing the relationship of certain variables back to the modeling conducted for the previous RTP/SCS may require MPO staff discretion and interpretation. For example, updated household demographic variables (such as household size) may result in a change to the regional population compared to the previously-submitted SCS. CARB staff expects a good-faith effort to construct a reasonable approximation. Exact accounting is not necessary.

[2] Where available and sufficient for forecasting purposes.

Notes: ABM = activity based model; HBO = home-based-other; HBSh = home-based-shopping; HBW = home-based-work; HH = household; mpg = miles per gallon; MPO = Metropolitan Planning Organization; TNC = transportation network company; VMT = vehicle miles traveled.

Per Capita GHG Emissions from Prior RTP/SCS

- Using the assumed values listed above in **Table 3** for exogenous variables, the MPO should conduct travel demand modeling for the previous RTP/SCS using these input variables. This result will be used as the basis for comparison in the **Incremental Progress** reporting component as part of CARB staff's subsequent SCS Evaluation Process.

Off-Model Strategies

- List all off-model strategies under consideration that may be used in the RTP/SCS including proposed emissions calculation methods and assumptions (See **Appendix E**)[3] with clearly cited sources
- Specify how the MPO will develop assumptions about an off-model RTP/SCS strategy, including:
  1) Participation rate or program utilization
  2) Expected effect on travel behavior and emissions and references/sources documented
  3) Rationale for why GHG emission reductions should be considered surplus/additional (e.g., goes beyond existing State programs)
- Region-specific data for off-model RTP/SCS strategy performance to date, adopted investment commitments, and project outcomes (e.g., existing program utilization)

In addition, MPO in its Technical Methodology submittal to CARB describe why a given strategy is not reflected in its travel demand modeling and why an off-model quantification approach is appropriate for a given strategy.

If an MPO includes an off-model strategy as part of its RTP/SCS, the MPO should continue to quantify the GHG emissions reduction benefits of that off-model strategy in all future RTP/SCSs. If the MPO is no longer implementing the off-model strategy, the MPO should document the termination of that off-model strategy in the Technical Methodology submittal. If the off-model strategy is now reflected in the travel demand modeling due to model upgrades or improved model sensitivity, the MPO should document plans to rely on the travel demand model output to quantify the GHG emissions reduction benefit of that strategy, and it will no longer be quantified off-model.

Other Data Collection Efforts

- May include, but are not limited to:
    - Data collected from regional surveys on travel behavior

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[3] If an MPO includes an off-model strategy as part of its RTP/SCS, the MPO should continue to quantify the GHG emissions reduction benefits of that off-model strategy in all future RTP/SCSs. If the MPO is no longer implementing the off-model strategy, the MPO should document the termination of that off-model strategy in the Technical Methodology submittal. If the off-model strategy is now reflected in the travel demand modeling due to model upgrades or improved model sensitivity, the MPO should document plans to rely on the travel demand model output to quantify the GHG emissions reduction benefit of that strategy, and it will no longer be quantified off-model.

- Compiled project information from local jurisdictions
- Census data
- Traffic counts

Note on the Technical Methodology

CARB understands MPOs are Board-driven agencies and RTP/SCS scenarios are developed through a robust public process. Upon submission of the Technical Methodology, CARB will receive the level of detail available at time of submission with more detail forthcoming as the Technical Methodology is developed through the RTP/SCS process. CARB staff will continue to work closely with the MPOs as preferred scenarios and assumptions are developed to ensure GHG emission reduction methodologies are clearly understood.

Appendix B: Additional Details for Model Sensitivity Tests

This section includes information CARB staff collects from MPOs to support the SCS Evaluation Process. As stated previously, if the MPOs validate and calibrate the land use and transportation models to meet the applicable requirements of the RTP Guidelines, then the model is considered valid. As part of CARB's SCS determination, CARB staff will review the model sensitivity test completed by the MPO. This section provides additional detail regarding CARB staff's use of standardized model sensitivity tests to determine whether an MPO's travel demand model is capable of reflecting VMT and associated GHG emissions reductions from stated RTP/SCS strategies. If the model is not sensitive to certain variables, **Appendix E** offers alternative (off-model) methods that MPOs may use to calculate the benefits of stated RTP/SCS strategies not captured in the travel demand model.

Sensitivity Tests

CARB staff requests MPOs to conduct travel demand model sensitivity for two reasons:

1) To examine the responsiveness of the travel demand model to RTP/SCS strategies
2) To ensure the model outputs are a reliable source for measuring the performance of the strategies

Generally, sensitivity tests involve systematically changing one RTP/SCS strategy-related model input variable at a time (e.g., transit frequency, auto operating cost, land use density), while keeping all other variables constant, to determine whether, and to what extent, key model outputs (i.e., VMT, mode share, vehicle trips) react to these changes. The analyses are expected to identify the direction and magnitude of the changes in model input variables to determine whether the model is adequately reflecting VMT and associated GHG emission reductions from specific RTP/SCS strategies. CARB staff analyzes whether MPO's sensitivity test results are within the range of values published in relevant empirical literature. This analysis is completed by identifying appropriate empirical literature for comparison with the results of the MPO sensitivity tests and then applying the elasticities found in the empirical literature to the outcomes of the MPO's sensitivity tests. In cases where sensitivity test results fall outside of the expected range and/or go in unexpected directions, MPO staff need to provide a clear explanation and supporting evidence, such as survey data, planning assumptions, modeling parameters, or other factors that could explain the response of the model to the tested RTP/SCS strategy.

An MPO only needs to conduct the applicable model sensitivity tests for RTP/SCS strategies that are represented within the travel demand model. If the MPO's model documentation clearly indicates that a RTP/SCS strategy is not represented in the model (e.g., the model does not have a transit network), then the MPO may note this conclusion, and does not need to conduct the respective sensitivity test. Additionally, if an MPO previously conducted a sensitivity test for a given RTP/SCS strategy as part of CARB's SCS Evaluation for the previous RTP/SCS, and no changes to the travel demand model have occurred since the last RTP/SCS was adopted, then the MPO may note this conclusion, and does not need to repeat the respective test. Finally, if an MPO does not propose a given RTP/SCS strategy as part of its RTP/SCS, then the MPO should note this, and does not need to conduct the respective sensitivity test.

The SCS Evaluation Process typically involves collaboration between MPO and CARB staff. The general process of conducting sensitivity tests and the roles and responsibilities of MPO staff and CARB staff is outlined below:

If an MPO does not propose a given RTP/SCS strategy as part of its RTP/SCS, then the MPO should note this, and does not need to conduct the respective sensitivity test.

Step 1: CARB and MPO staff develop a list of sensitivity tests representative of key RTP/SCS strategies specific to each MPO (e.g., increased density, improved transit service). The desired inputs and outputs are listed below by the type of RTP/SCS strategy. CARB and MPO staff then establish a timeline for completing the sensitivity tests and review of the results.

Step 2: MPO staff conduct the chosen sensitivity tests. CARB staff can provide additional guidance and technical support as needed. MPO staff can either submit test results to CARB staff upon completion of each test (preferred), or upon completion of all sensitivity tests.

Step 3: CARB staff identifies the appropriate empirical literature for comparison with the results of the MPO sensitivity tests. CARB staff recommends starting with the list of empirical literature reviewed under contract with University of California: www.arb.ca.gov/cc/sb375/policies/policies.htm. CARB staff conduct sensitivity test analyses by interpreting the change of direction and magnitude of the outputs with respect to the change of selected variables. CARB staff then applies the elasticities found in the empirical literature to the input changes in the MPO's sensitivity tests. The result is an expected range of outputs based on the empirical literature, which is compared with the outputs of the MPO model sensitivity tests reported by MPO staff. CARB staff considers the model to be sensitive to the RTP/SCS strategy if the sensitivity test outputs are consistent with the empirical literature. CARB staff then determines if the sensitivity test outputs fall within the range of expected outputs based on the empirical literature. (Note: the empirical literature is a starting point for discussion with MPO staff, not a benchmark).

Step 4: Once initial analyses of the sensitivity test results are completed, CARB staff will share findings and an initial assessment of the model sensitivity to the selected variables with MPO staff. If the sensitivity test results fall outside the range of expected outputs, CARB staff requests that MPO staff provide additional information (e.g., local information, travel surveys, additional studies) to explain model behavior. However, CARB staff acknowledge that empirical literature may not sufficiently represent local conditions.

Step 5: CARB staff will document the final assessment of the model sensitivity tests to key RTP/SCS strategies in the SCS Evaluation Staff Report.

The different categories of sensitivity tests that CARB typically requests from MPOs based on the RTP/SCS strategies employed are discussed in the following section.

- Land Use-Related Sensitivity Tests
- Transit Infrastructure and Active Transportation-Related Sensitivity Tests
- Local/Regional Pricing Related Sensitivity Tests
- New Mobility Related Sensitivity Tests
- Exogenous Variable Sensitivity Tests

If a given strategy is not represented by one of the listed sensitivity tests, then CARB staff will provide guidance to MPO staff on selecting the model variables that are related to the applicable strategy, and the outputs used to develop performance indicators. Note that each MPO may estimate the performance indicators slightly different due to data limitations as part of the sensitivity tests, and CARB staff will coordinate with MPO staff regarding the performance indicators for each sensistivity test.

Land Use-Related Sensitivity Tests

Land Use-Related Sensitivity Tests evaluate land use related strategies that reduce VMT and GHG emissions through methods such as, but not limited to, infill development, increase in density, and proximity to transit. Common variables CARB may recommend to MPOs for inclusion in the Land Use-Related Sensitivity Tests are based upon the specific RTP/SCS strategies under evaluation: regional accessibility, mix of land uses, proximity to transit, street pattern, residential density, job/housing balance etc. **Table 4** summarizes each Land Use-Related Sensitivity Test, recommended variation in test variable (scenarios), and corresponding inputs and outputs.

Table 4. Land Use Sensitivity Tests and Reporting

Sensitivity Test	Model Input(s)	Scenario(s)	Output(s)[4]
Regional Accessibility	Transportation network density	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by purpose • Mode share • Transit ridership • VMT
Mix of Land Uses	Single Family vs. Multi-Family housing units	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by purpose • Mode share • Transit ridership • VMT
Proximity to Transit	Number of households and employment centers close to transit stops	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by purpose • Mode share • Transit ridership • VMT
Street Pattern	Increase intersection density	Increase 5%, 10% Decrease 5%, 10%	• Vehicle trips by purpose • Mode share • VMT
Residential Density	Residential density	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by purpose • Mode share • Transit ridership • VMT
Job/Housing Balance	Number of jobs and housing units at the sub-regional level	Based on the base case job/housing ratio, CARB would assign applicable test scenarios upon discussion with the MPO	• Vehicle trips by purpose • Mode share • Transit ridership • VMT • Peak-hour VMT • HBW trip length or travel time • Vehicle trips by trip type (II, IX/X, XX) (if the MPO region generally experiences in-commuter or out-commuter traffic)

Given the interdependence among some land use-related model inputs and assumptions, CARB staff recommend MPOs use any of the two approaches below to when conducting sensitivity tests on land use variables:

[4] Model outputs are generally requested at the regional level, however, dependent on the coverage of the particular strategy and the corresponding responsiveness of the model, model outputs may be requested at the sub-regional geographic resolution in the region.

Controlled Variable Approach

The *Controlled Variable Approach* is simply hypothesis testing which holds all other variables constant, neglecting the supply-demand interaction between inter-dependent variables in reality, to determine the change in model outputs (e.g., VMT, VHT, vehicle trips, mode share) with respect to the change in a single land use related variable (e.g., residential density, employment density, compact housing development). The MPO must not change keep regional totals for employment, household and population, but change the composition and/or special allocation of these components.

Cross-sectional Analysis

In reality, when changing any demographic factors, other factors may be affected. For example, increasing residential or employment density adds population for jobs to a given area. Such a change can affect the mix of land uses and regional accessibility, obscuring the particular relationships being researched. To capture this effect while testing the model's sensitivity to land use variables, MPOs may use a *Cross-Sectional Analysis Approach*, which utilizes statistics to help sort out the relationships among multiple input and output variables. The process starts with a single model run to find the correlations between land use and transportation factors to VMT, transit use, and the frequency of walking to a destination. The more detailed the information modeled, the greater the ability to identify precise correlations between variables.

Transit Infrastructure and Active Transportation-Related Sensitivity Tests

Transit Infrastructure and Active Transportation-Related Sensitivity Tests evaluate transit and active transportation-related strategies that reduce VMT and GHG emissions through methods such as, but not limited to, more frequent transit service, expansion and/or extension of the transit network, improvement for bike and pedestrian infrastructure, first/last-mile connections, and complete streets. Common variables CARB may recommend to MPOs for inclusion in Transit Infrastructure and Active Transportation-Related Sensitivity Tests are based upon the specific RTP/SCS strategeies under evaluation: transit frequency, transition expansion and/or extension, active transportation facilities, and bike share facilities. **Table 5** summarizes each Transit Infrastructure and Active Transportation-Related Sensitivity Test, recommended variation in test variable (scenarios), and corresponding inputs and outputs.

Table 5. Transit and Active Transportation Sensitivity Tests and Reporting

Sensitivity Test	Model Input	Scenario(s)	Output(s)[5]
Transit Frequency	Transit service headway	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by purpose • Mode share • Transit ridership • VMT
Transit Operation Expansion and/or extension	Transit operation miles	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by purpose • Mode share • Transit ridership • VMT
Active Transportation Facility[6]	Walk/bike lane miles	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by purpose • Mode share • Transit ridership • VMT
Bike share Facility	Mode share of bike trips[7]	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by purpose • Mode share • Transit ridership • VMT

Local/Regional Pricing Related Sensitivity Tests

Local/Regional Pricing Related Sensitivity Tests evaluate local/regional pricing-related strategies that reduce VMT and GHG emissions through methods such as, but not limited to, tolled roadways, reduction in transit fare cost, mileage-based pricing, cordon pricing, and parking pricing. Common variables CARB may recommend to MPOs for inclusion in Local/Regional Pricing Related Sensitivity Tests are based upon the specific RTP/SCS strategies under evaluation: roadway pricing, transit fare cost, and cost of parking. **Table 6** summarizes each Local/Regional Pricing-Related Sensitivity Test, recommended variation in test variable (scenarios), and corresponding inputs and outputs.

[5] Model outputs are generally requested at the regional level, however, dependent on the coverage of the particular strategy and the corresponding responsiveness of the model, model outputs might be requested at the scale matching the actual affected area(s) in the region.
[6] Model sensitivity tests for active transportation strategy would only apply if the MPO's regional travel model has a non-motorized network or equivalent component to model bike and walk trips.
[7] This input can be the foreseeable increase in bike trips due to improved/new bike share programs from the SCS.

Table 6. Sensitivity Tests on Pricing Variables and Reporting

Sensitivity Test	Model Input	Scenario(s)	Output(s)[8]
Managed/Tolled Lane	Managed/Tolled lane miles OR auto operating cost	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by purpose • Mode share • Transit ridership • VMT
Mileage-based Fee	Auto operating cost	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by purpose • Mode share • Transit ridership • VMT
Transit Fare	Cost of transit fare	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by purpose • Mode share • Transit ridership • VMT
Various Parking Cost	Cost of parking	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by purpose • Mode share • Transit ridership • VMT

New Mobility Related Sensitivity Tests

New Mobility Related Sensitivity Tests evaluate new mobility-related strategies that can potentially reduce VMT and GHG emissions through methods such as, but not limited to, increasing access to the regional electric vehicle charging network, promoting ride-hailing and ridesharing, intelligent transportation systems, and transportation systems mangement programs. Since there are limited studies evaluating the impact of new mobility-related strategies on VMT and GHG emission reductions, the current practice of the quantification of the GHG benefit is generally conducted through off-model analysis and remains an emerging area for GHG emission reduction quantification. The examples of New Mobility Related Sensitivity Tests, presented in **Table 7,** are based on related modeling variables to reflect these strategies.

[8] Model outputs are generally requested at the regional level; however, dependent on the coverage of the particular strategy and the corresponding responsiveness of the model, model outputs might be requested at the scale matching the actual affected area(s) in the region.

Table 7. Sensitivity Tests on New Mobility Variables and Reporting

Sensitivity Test	Model Input	Scenario(s)	Output(s)[9]
EV Charging Infrastructure	Number of electric vehicles	Increase 25%, 50% Decrease 25%, 50%	• eVMT
Dynamic Ride-hailing	Number of trips by dynamic ride-hailing for different trip purposes	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by mode • Mode share • VMT
Carpooling/Vanpooling	Number of trips by carpool/vanpool for different trip purposes	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by mode • Mode share • VMT

Exogenous Variable Sensitivity Tests

Exogenous Variable Sensitivity Tests evaluate exogenous factors, such as household income, growth forecast, and cost of travel, which are all important assumptions in an MPO's travel demand model and can influence a typical SCS' ability to meet the assigned GHG emission reduction target. MPOs should conduct sensitivity tests on some of the most common exogenous variables in the travel demand model: income distribution, auto operating cost, and mix of demographics. **Table 8** summarizes recommended variation in test variable (scenarios), and corresponding inputs and outputs.

Table 8. Sensitivity Tests on Assumptions-Related Variables

Sensitivity Test	Model Input	Scenario(s)	Output(s)[10]
Income Distribution	Median and average household income; Number of household	Low High	• Vehicle trips by mode • Mode share • VMT
Auto Operating Cost	Auto operating cost (and component[s] if applicable)	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by mode • Mode share • VMT
Mix of Demographics	Age distribution; Or other characteristics depending on the interested aspect of demographic to test	Various, upon discussion with MPO staff	• Vehicle trips by mode • Mode share • VMT

Model outputs are generally requested at the regional level, however, dependent on the coverage of the particular strategy and the corresponding responsiveness of the model, model outputs might be requested at the scale matching the actual affected area(s) in the region.
[10] Ibid.

How does CARB use this data?

The assessment on the overall sensitivity of the modeling tools will provide CARB staff the technical evidence and level of confidence in the accuracy of the modeled per capita GHG emission reductions for each strategy. The outcome of this evaluation method will help CARB staff determine whether the model is capable of reflecting the benefits of RTP/SCS strategies. Where MPO models are not appropriately sensitive to strategy variables, MPOs can then consider using off-model quantification methods to reflect the benefits of the RTP/SCS strategies, as discussed in the following section.

CARB staff recognize that California's 18 MPOs represent a wide variety of land use types, transportation systems, population centers, and existing development. RTP/SCS strategies work differently in each region depending on a number of factors including the existing infrastructure, growth allocation (e.g., urban, suburban, or rural), and the natural environment. Consequently, CARB recognizes each MPO will report the information consistently, but it may not be comparable across MPOs.

Appendix C: RTP/SCS Data and Performance Indicators for Strategy Evaluation[11] and Description of other Key Terms

This section provides definitions and examples for calculating RTP/SCS data and performance indicators needed by CARB in an MPO's data submittal.

Land Use Data

- **Total Developed Acres:** Land acreage developed or improved for urban purposes, including acreage for public and private rights-of-way and public facilities.
- **Net Residential Density:** The total number of permanent residential dwelling units divided by total developed acreage (including public and private right-of-way and public facilities).

Transportation Network Data

- **Bike and Pedestrian Lane Miles:** The total number of class I, II, and IV bicycle path facility miles and pedestrian pathway miles in the region.
- **High-Quality Transit:** Fixed route bus or rail service with transit headways no longer than 15 minutes during peak commute hours.
- **Roadway Lane Miles by functional classification:** The total number of roadway lanes by facility type (e.g., freeway, expressway, local roads) in the region, measured in miles. MPOs should report the number of managed lane miles (e.g., high-occupancy vehicle [HOV] and HOT lane miles) separately from freeway/expressway general purpose lane miles.
- **Transit Headways:** The average public transit service frequency in minutes.
- **Transit Operation Miles:** The miles that vehicles are scheduled to or actually travel while in revenue service, which means the time when a vehicle is available to the general public and there is an expectation of carrying passengers.
- **Transit Vehicle Service Hours:** The hours that vehicles are scheduled to or actually travel while in revenue service and are available to the general public with an expectation of carrying passengers.

[11] The preferred format for RTP/SCS Data and Performance Indicators is Excel, although MPOs may provide data in alternative formats, as applicable, with an explanation for why the alternative format is provided.

RTP/SCS Performance Indicators

- **Average Trip Length:** The regional average daily trip distance (miles/day), by travel mode and trip purpose, calculated using the MPO's travel demand model.
- **Average Travel Time:** The regional average travel time (minutes) by trip purpose (for commute and non-commute trips), by travel mode, and for low-income populations, calculated using the MPO's travel demand model.
- **Employment Near Transit:** The percentage of jobs within a ½ mile of transit stations and stops.
- **Household vehicle ownership:** The average number of light-duty vehicles registered (i.e., LDA, LDT1, LDT2, and MDV vehicle categories) per household.
- **Housing Near Transit**: The percentage of housing units within a ½ mile of transit stations and stops.
- **Housing Units:** The number of new housing units (e.g., total number of new housing units, single-family homes, or multi-family units).
- **Land Consumption:** The percentage of urbanized land**.**
- **Mode Share:** The percentage of average daily trips by travel mode (e.g., single-occupant vehicle, high-occupancy vehicle, transit, non-motorized).
- **Residential Density:** The number of dwelling units per acre of land.
- **Seat Utilization:** The average daily percentage of occupied vehicle seats on the roadway network, including for passenger vehicles and transit buses.
- **Transit Ridership:** The total number of one-way linked or unlinked average daily transit passenger trip boardings on public transportation in a given time period, calculated using the MPO's travel demand model or from data available from transit agencies.
- **Vehicle Miles Traveled:** The average daily (weekday) VMT calculated using the MPO's travel demand model.

Other Key Terms

- ***Active Transportation*****:** Modes of transportation, such as biking, walking, and wheeling (e.g., e-bikes, e-scooters, and the use of personal assistive mobility devices for people with disabilities).
- ***Elasticity:*** The quantitative relationship between the change in the RTP/SCS Strategies and the SCS Performance Indicator, which can be obtained from literature, MPO's sensitivity tests, and/or other empirical sources.
- ***Exogenous Variables*****:** Independent variables that can affect the model (travel demand, regression analysis) as control variables. Examples include, but are not limited to, auto operating cost, demographics, household demographics, and household income.

- ***Forecasted Development Pattern:*** An MPO-projected land use development pattern integrated with the regional transportation network used to calculate GHG emissions from automobiles and light trucks.
- ***High Quality Transit Area*:** See Transit Priority Area.
- ***Household Vehicle Ownership*:** The average number of light-duty vehicles (i.e., LDA, LDT1, LDT2, and MDV vehicle categories) registered per household.
- ***Household VMT*:** VMT per household representing light-duty vehicle VMT within an MPO's boundary generated by residents of households within the MPO for normal commuting purposes (e.g., going to work, school, shopping, and personal business) and excludes group quarters and visitors. Please also see *per capita VMT*.
- ***Load Factor*:** See Seat Utilization.
- ***Low Income Population*:** People with household income at or below U.S. poverty guidelines.
- ***Model Validation*:** The process of calibrating and confirming MPO's models against observed data (e.g., historical land use patterns, traffic counts, household travel survey) to ensure the model is adequately and reasonably representing the base year conditions.
- ***New Mobility*:** Technological and innovative advances that can modify people's travel behavior often on an as-needed basis.
- ***Off-Model*:** Quantification methods that occur outside the MPOs land use and travel demand model, typically using spreadsheet calculations and assumptions based on empirical evidence and other clearly cited supporting literature and documentation.
- ***Per Capita VMT*:** VMT per person representing light-duty vehicle VMT within an MPO's boundary generated by each person within the MPO for normal commuting purposes (e.g., going to work, school, shopping, and personal business) and excludes group quarters. Please also see *Household VMT*.
- ***Preferred Scenario*:** The approved scenario adopted by an MPO Board to meet the SB 375 GHG emission reduction targets.
- ***RTP/SCS Base Year*:** The future transportation system that will result from current programs included in the RTP/SCS, which include (1) all in-place regionally significant highway and transit facilities, services and activities; (2) all ongoing travel demand management or transportation system management activities; and (3) completion of all regionally significant projects, regardless of funding source, which are currently under construction or are undergoing right-of-way acquisition (except for hardship acquisition and protective buying), come from the first year of the previously conforming transportation plan and/or TIP; or have completed the NEPA process.

- ***Scenarios*****:** Combinations of RTP/SCS strategies used to depict future conditions, benefits, and consequences.
- ***Sensitivity Test*****:** The process where CARB determines whether the model results are reasonable and reliable by comparing the results of sensitivity tests with peer-reviewed literature.
- ***Target Base Year*****:** Targets for reducing GHG emissions are defined in relation to 2005, the GHG emission reduction target base year for all MPOs.
- ***Transit Priority Area*****:** An area within a ½ mile of transit stations and stops that are existing or planned.
- ***Transportation Project List*****:** List of projects within the RTP/SCS that includes: project costs, funding sources (if known/available), project time period, and project locations.

Appendix D: Guidance on Technical Issues

EMFAC Adjustment Methodology

As part of the RTP/SCS development process, MPOs need to provide the estimated CO_2 emission reductions from the proposed RTP/SCS. Currently, MPOs use the CARB EMission FACtor Model (EMFAC) to estimate passenger vehicle CO_2 emissions by providing region-specific VMT and speed profiles generated by the travel demand model. MPOs then divide the estimated passenger vehicle CO_2 emissions by the residential population to obtain CO_2 emissions per capita, to demonstrate SB 375 GHG emission reduction target achievement. EMFAC is a California-specific inventory model developed by CARB that calculates emissions inventories for motor vehicles, including passenger cars to heavy-duty trucks, operating on highways, freeways, and local roads in California. CARB, as part of its own air quality and climate planning programs, regularly updates the EMFAC model to reflect the latest planning assumptions (such as vehicle fleet mix) and updated emissions testing data.

SB 375 indicates that MPOs may not take credit for state programs and policies that improve vehicle emission standards, changes in fuel composition, and other State measures that will reduce GHG emissions, such as the Advanced Clean Cars (ACC) and the Low Carbon Fuel Standards (LCFS), when demonstrating GHG emission reduction targets. Therefore, in order to normalize the effects from updated versions of EMFAC, CARB staff developed an EMFAC Adjustment Methodology. This methodology, outlined below, has been used by all MPOs in their previous RTP/SCSs.

With changes in the model data, the resulting fleet-wide CO_2 emission rates vary from one version of EMFAC to the next. These variations solely due to changes within EMFAC can change the performance of a MPOs RTP/SCS, even if nothing else changes in the RTP/SCS. Therefore, for the third round of RTP/SCSs, MPOs should continue to use this approach. MPOs should use the exact same methodology and version of EMFAC as used in the second RTP/SCS for the third. Effectively, this ensures that should nothing else change, the performance of the third RTP/SCS will be identical to the second RTP/SCS.

MPOs should use the exact same methodology and version of EMFAC as used in the second RTP/SCS for the third.

EMFAC Adjustment Background

In 2010, CARB established regional SB 375 GHG emission reduction targets in the form of a percent reduction per capita from 2005 for passenger vehicles using the CARB emission factor model, EMFAC2007. EMFAC is a California-specific computer model that calculates weekday emissions of air pollutants from all on-road motor vehicles including passenger cars, trucks, and buses. CARB updates the EMFAC model periodically to reflect the latest planning assumptions (such as vehicle fleet mix) and emissions estimation data and methods. Since the time when targets were set using EMFAC2007, CARB has released three subsequent versions, EMFAC2011,[12] EMFAC2014,[13] and EMFA2017[14].

CARB has improved the carbon dioxide (CO_2) emission rates in EMFAC2011 and EMFAC2014, based on recent emission testing data from newer vehicle technologies and updated energy consumption for air conditioning. In addition, vehicle fleet mix has been updated in EMFAC2011 and again in EMFAC2014 based on the latest available Department of Motor Vehicle data at the time of model development. These changes have lowered the overall CO_2 emission rates in EMFAC2011, EMFAC2014, and EMFAC2017 compared to EMFAC2007.

EMFAC Adjustment Purpose

Some MPOs used EMFAC2007 to quantify GHG emissions reductions from their first RTP/SCS; others used EMFAC2011. As MPOs estimate GHG emissions reductions from subsequent RTP/SCSs, the latest approved version of EMFAC should be used, however using a different model will influence estimates and the ability to achieve SB 375 targets. The goal of this methodology is to hold each MPO to the same level of stringency in achieving SB 375 targets regardless of the version of EMFAC used in the second RTP/SCS.

CARB staff has developed this methodology to allow MPOs to adjust the calculation of percent reduction in per capita CO_2 emissions used to meet the established targets when using either EMFAC2011 or EMFAC2014 for their subsequent RTP/SCS. This method will neutralize the changes in fleet average emission rates between the version used for the first RTP/SCS and the version used for the second RTP/SCS. The methodology adjusts for the small benefit or disbenefits resulting from the use of a different version of EMFAC by accounting for changes in emission rates, and applies an adjustment when quantifying the percent reduction in per capita CO_2 emissions using EMFAC2011 or EMFAC2014.

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[12] EMFAC2011 was approved by the United States Environmental Protection Agency in March 2013.
[13] EMFAC2014 was approved by the United States Environmental Protection Agency in December 2014.
[14] EMFAC2017 was approved by the United States Environmental Protection Agency in August 2019.

EMFAC Adjustment Applicability

The adjustment is applicable when the first RTP/SCS was developed using either EMFAC2007 or EMFAC2011 and the updated RTP/SCS will be developed using a different version of the model (EMFAC2011 or EMFAC2014).

- Hold the 2005 baseline CO_2 per capita estimated in the first RTP/SCS constant. Use both the human population and transportation activity data (VMT and speed distribution) from the first RTP/SCS to calculate the adjustment.
- Add the adjustment to the percent reduction in CO_2 per capita calculated with EMFAC2011 or EMFAC2014 for the second RTP/SCS. This will allow equivalent comparison to the first RTP/SCS where emissions were established with EMFAC 2007 or EMFAC2011.

Example Adjustment Calculation (hypothetical for illustration purposes):

In this example, the first RTP/SCS was developed using EMFAC2007 and the second RTP/SCS was developed using EMFAC2011 to calculate the CO_2 per capita.

Step1: Compile the CO_2 per capita numbers from the MPO's first adopted RTP/SCS using EMFAC 2007 without any off-model adjustments for calendar years (CY) 2005, 2020, and 2035 for passenger vehicles.

Calendar Year	EMFAC2007 CO_2 Per capita (lbs/day)
2005	30.0
2020	28.8
2035	27.6

Step 2: Calculate the percent reductions in CO_2 per capita from the 2005 base year for CY 2020 and 2035 from Step 1.

Calendar Year	EMFAC2007 Percent Reductions (%)
2020	4.0%
2035	8.0%

Step 3: Develop the input files for the EMFAC2011 model using the same activity data for CY 2020 and 2035 from the first adopted RTP/SCS (same activity data used in Step 1) and execute the model using SB 375 Mode.

Step 4: Calculate the CO_2 per capita for CY 2020 and 2035 using the EMFAC2011 output from Step 3; do not include Pavley I, LCFS, and ACC benefits for passenger vehicles.

Calendar Year	**EMFAC2011 CO_2 Per capita (lbs/day)**
2020	28.2
2035	27.9

Step 5: Calculate the percent reductions in CO_2 per capita for CY 2020 and 2035 calculated in Step 4 from base year 2005 established in Step 1.

Calendar Year	**EMFAC2011 Percent Reductions (%)**
2020	6.0%
2035	7.0%

Step 6: Calculate the difference in percent reductions between Step 5 and Step 2 (subtract Step 5 results from Step 2 results) for CY 2020 and 2035; this yields the adjustment for the respective CY.

Calendar Year	**EMFAC2011 Adjustment (%)**
2020	-2.0%
2035	+1.0%

Step 7: Develop the input files for the EMFAC2011 model using the activity data from the new/second RTP/SCS for CY 2020 and 2035 without any off-model adjustments and execute the model using SB 375 Mode.

Step 8: Calculate the CO_2 per capita for CY 2020 and 2035 using the EMFAC2011 output from Step 7; do not include Pavley I, LCFS, and ACC benefits for passenger vehicles.

Calendar Year	**EMFAC2011 CO_2 Per capita (lbs/day)**
2020	26.4
2035	26.1

Step 9: Calculate the percent reductions in CO_2 per capita for CY 2020 and 2035 calculated in Step 8 from base year 2005 established in Step 1.

Calendar Year	**EMFAC2011 Percent Reductions (%)**
2020	12.0%
2035	13.0%

Step 10: Add the adjustment factors from Step 6 to the percent reductions calculated for the new/second RTP/SCS (Step 9) using EMFAC 2011 for CY 2020 and 2035.

Calendar Year	Adjusted Percent Reductions (%)
2020	10.0%
2035	14.0%

Follow the same steps to adjust for use of EMFAC2007 or EMFAC2011 to EMFAC2014. Do not include any off-model adjustments during application of the EMFAC adjustment factor.

2005 Base Year Adjustment

SB 375 GHG emission reduction targets are set relative to 2005 emissions levels. At the time of writing, CARB has conducted more than 25 SCS Evaluations. Some MPOs have requested to update or recalibrate the 2005 reference year per capita emissions based on new information in subsequent SCS updates, which CARB staff have accommodated. At this time, the base year 2005 GHG emissions data and 2005 population should be well documented and validated against census data from 2005. For this reason, under the SCS Evaluation Process, CARB will generally no longer accept adjustments to 2005 per capita GHG emissions unless there is an absolute need for making an adjustment. If the MPO has upgraded its travel demand model to specify new variables that were not available in the previous version of the model, and the upgraded model validates to 2005 conditions better than the previous model (as documented in MPO model documentation), then CARB staff recommends the MPO re-specify its 2005 per capita GHG emissions and document the basis for the change.

Rounding Protocol for Reporting GHG Emission Reductions

MPOs that rely on a combination of modeled and off-model methods to estimate per capita GHG emission reductions from its RTP/SCS should round to the nearest integer percent, but only after <u>all</u> modeled and off-model GHG calculations have been summed. In other words, rounding to the nearest integer should only occur at the last step of the MPO's calculation of whether the RTP/SCS meets its assigned GHG emission reduction targets. The following example illustrates the rounding methodology:

1. An MPO has an assigned GHG emission reduction target of -19% in 2035.
2. The MPO estimates a modeled per capita GHG emission reduction of -15.35% and estimated contribution from three off-model strategies of -1.74%, 1.45% and 0.26% respectively in 2035 for a combined -18.8% reduction in 2035.
3. This MPO would round to the nearest integer percent (i.e., -19%) to meet its GHG emission reduction target.

Auto Operating Cost

There are many other variables, such as economic growth, value of time, availability of alternative transportation, urban form, parking, and vehicle costs, which can influence travel behavior and VMT. Importantly, research shows that the impact of these variables is not uniform. For example, the value of time and other costs, such as parking, have a direct influence on the frequency of trips and the mode choice of individuals and households. On the other hand, vehicle ownership or operating costs may not have same level of influence on trips and mode choice. Evidence from real world data indicates that while fuel price is a statistically significant variable impacting driving behavior, fuel economy is not. In fact, some researchers consider the fuel economy impact on VMT is potentially near zero.[15]

Auto operating cost (AOC) is a key input in an MPO's travel demand model used to develop the RTP/SCS. AOC is a critical parameter in the mode choice components of the travel demand model, which affects travel behavior and VMT. Published literature contains a wide range of elasticities about the impact of vehicle operating costs on travel behavior and VMT. In the short-run, people change travel behavior by making fewer vehicle trips through trip-chaining[16] to multiple destinations and exploring alternative modes due to an increase in AOC or fuel price. In the long-run, it can affect transportation mode, choice of residency and/or workplace location, vehicle occupancy, and vehicle efficiency (i.e., purchase of more fuel efficient vehicles). Research has shown a 10% increase in fuel price can reduce vehicle travel by 0.26% and 1.31% in the short-run and long-run, respectively.[17] However, elasticities may vary by context, and this variation in context depends on the availability of alternative modes, the specific characteristics of the region, and the socioeconomic background of travelers in that region.

During the first and second round of SCS development, each MPO used its own method for estimating AOC. This resulted in inconsistencies in approach between regions, and in some cases errors. For example, some MPOs considered only fuel price for determining AOC, while others included maintenance, repair, and tire wear costs. A few MPOs used a fixed AOC for all years in the RTP/SCS, while others varied the AOC over time. There were also instances where MPOs only accounted for the cost of gasoline

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[15] United States Environmental Protection Agency. *The Rebound Effect from Fuel Efficiency Standards: Measurement and Projection to 2035*. July 2015. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi/P100N11T.PDF?Dockey=P100N11T.PDF.

[16] A trip chain is any travel, or tour, between two anchors (e.g., between home and work) that is direct or has an intervening stop of 30 minutes or less.

[17] Hymel, K. M., Small, K.A, & Van Dender, K. (2010). *Induced Demand and Rebound Effects in Road Transport. Transportation Research Part B*, 44(10), 1220-1241.

fuel, while other fuel costs, such as electricity and hydrogen for alternative-fuel vehicles, were not included. In some instances, MPOs had inconsistent forecasting methodology of fuel prices and incorrectly adjusted for fuel regulations (e.g., LCFS) in estimating fuel economy.

The quality and consistency of model inputs are crucial to estimate travel activities and patterns. To assist MPOs with estimating AOC, CARB staff developed an AOC Calculator tool, which is available for download from CARB's website site at: https://ww2.arb.ca.gov/resources/documents/scs-evaluation-resources. The purpose of the AOC Calculator tool is to bring consistency across MPOs in the approach and variables used to estimate AOC and forecasting fuel price and non-fuel related costs. Further, the AOC Calculator tool will bring uniformity in estimating fuel economy across MPOs both in base and future years. In the future, CARB's AOC Calculator tool and methodology will be updated to include other costs, including depreciation, license, registration and taxes.

Methodology

AOC is derived from the cost of fuel and non-fuel related costs (maintenance, repair, and tire wear). In addition to calculating AOC for gasoline- and diesel-fueled vehicles, this tool also calculates AOC for alternative fuel-based vehicles, such as electric, hydrogen, and gasoline-electric (hybrid). The fuel price in this tool is based on the California Energy Commission's (CEC) statewide estimates, but can be adjusted to varying regional conditions, such as regionally adjusted U.S. DOE Fuel Forecasts.

The equation used to calculate AOC in the tool is shown below:

$$AOC = \sum \left(\frac{FC_i * 100}{FE_i} + MRT_i \right) * \frac{VMT_i}{VMT}$$

where:
AOC = Calculated auto operating cost

FC_i = Fuel Cost of specific fuel type i obtained from the CEC ($Dollars/Gasoline Gallon Equivalent [GGE])

FE_i = Fuel Efficiency (VMT/Fuel Usage) of specific fuel type i obtained from EMFAC2017 (Miles/Gallon)

MRT_i = Maintenance, Repair, and Tires (MRT) costs of specific fuel type i obtained from the American Automobile Association (AAA)[18] *(Cents/Mile)*

100 = Conversion factor converting dollars to cents

VMT_i = VMT by vehicles using fuel type i

VMT = Total light duty vehicle VMT in the region

Input Data Sources

The default fuel price is based on the CEC Transportation Energy Demand Forecast;[19] non-fuel costs are based on information available from the American Automobile Association (AAA);[20] and fuel economy is based on EMFAC2017.[21] However, MPOs can utilize different inputs if other sources better capture regional conditions and variables. MPOs should clearly document its data sources, procedures, and assumptions when adjusting for local conditions.

Fuel Cost

CEC provided CARB with the most recent fuel costs for gasoline, diesel, hydrogen, and electricity, for various years, in $2015 dollars. To adjust for inflation when converting $2015 dollars to $2017 dollars, CEC recommended an adjustment factor of 1.034 for the two-year period, (equal to 1.69% per year). CEC prepared the fuel costs using an improved methodology, more recent base year, and represents the current CEC price forecast.

CEC provided CARB with historical gasoline and diesel fuel prices from 2000 to 2017 and projected prices from 2018-2030. From 2031-2050, gasoline and diesel fuel prices were assumed to be constant at 2030 level. CEC provided CARB hydrogen fuel and

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[18] American Automobile Association. *Your Driving Cost: How much are you really paying to drive? 2017 Edition. Available at:* http://exchange.aaa.com/wp-content/uploads/2017/08/17-0013_Your-Driving-Costs-Brochure-2017-FNL-CX-1.pdf.

[19] California Energy Commission. *Revised Transportation Energy Demand Forecast, 2018-2030.* Publication Number: CEC-200-2018-003. February 2018. Available at: https://efiling.energy.ca.gov/getdocument.aspx?tn=223241.

[20] Ibid.

[21] California Air Resources Board. *Mobile Source Emissions Inventory – Categories EMFAC2017*. Available at: https://www.arb.ca.gov/msei/categories.htm#onroad_motor_vehicles.

electricity prices from 2015-2030. From 2031-2050, hydrogen fuel and electricity prices were assumed to be constant at 2030 level. CEC's historical and projected fuel prices for gasoline, diesel, hydrogen, and electricity after removing the effects of inflation are presented in **Table 9**.

Table 9. CEC Historical and Projected Fuel Prices in $2017 Dollars (Dollar per Gasoline Gallon Equivalent[22])

Calendar Year	California All Grades All Formulations Retail Gasoline Prices*	California No 2 Diesel Ultra Low Sulfur Retail Prices*	Hydrogen[1]	Electricity[1]
2016	2.84	2.71	16.15	5.98
2020	3.45 (21%)	3.34 (23%)	14.80 (-8%)	6.45 (8%)
2025	3.90 (37%)	3.78 (39%)	12.56 (-22%)	6.57 (10%)
2030	4.18 (47%)	4.16 (54%)	10.32 (-36%)	6.61 (11%)

[1] CEC prices are presented in 2017 dollars, with percent (%) increases or decreases relative to 2016 listed in parentheses.

Fuel Efficiency

The AOC Calculator tool provides fuel efficiency separately for gasoline-powered vehicles, diesel-powered vehicles, hydrogen-powered vehicles, electric vehicles, and plug-in hybrid electric vehicles (PHEV), estimated by EMFAC 2017 and CARB Vision 2.1[23] Scenario Modeling System (Vision).

EMFAC incorporates ACC/Pavley rules to estimate VMT and fuel usage from low-emission vehicles (LEV) and zero emission vehicles (ZEV). The LEV regulations reduce criteria pollutants and GHG emissions from light- and medium-duty vehicles, while the ZEV regulation requires manufacturers to produce an increasing number of pure ZEVs (i.e., battery electric and fuel cell electric vehicles), with provisions to also produce PHEV in the 2018 through 2025 model years. The impacts of all these regulations on fuel efficiency have been incorporated into the AOC tool. To obtain fuel efficiency (in miles per GGE), CARB staff divided the light-duty vehicle (LDV) VMT by the light-duty vehicle fuel usage and energy consumption from the EMFAC2017 and Vision models, respectively. LDV are comprised of passenger cars (LDA), and three classes of trucks (LDT1, LDT2, and MDV).

The equation used to calculate Fuel Efficiency is shown below:

[22] GGE for Diesel (gallon) - 1.155; Electricity (kWh) - 0.031; Hydrogen (kg) -1.019.

[23] The analysis using the Vision Scenario Modeling System used Vision 2.1 updated to reflect fleet characteristics consistent with EMFAC2017.

$$LDV\ Fuel\ Efficiency\ (miles\ per\ gallon) = \frac{LDV\ VMT}{LDV\ Fuel\ Use}$$

where:

LDV VMT = Statewide VMT by vehicles of a specific fuel type, obtained from the EMFAC model

LDV Fuel Use = Statewide Fuel Usage (gallons of gasoline equivalent) by vehicles of a specific fuel type, obtained from the EMFAC and Vision models

For each fuel-type the fuel-based AOC is calculated by dividing the fuel cost (dollar per GGE) by fuel efficiency (in miles per GGE), with a conversion factor of 100 to convert from dollars to cents.

Maintenance Costs

AAA provides 2017 maintenance costs ($2017 dollars) for gasoline, electric, and hybrid vehicles for sedans (small, medium, and large), SUVs (small and medium), minivans, half ton pickups, hybrid vehicles, and electric vehicles (see **Table 10**).

Table 10. AAA 2017 Vehicle Maintenance Costs (Cents per Mile)

AAA Vehicle Category[24]	Small Sedan	Medium Sedan	Large Sedan	Small SUV (FWD)	Medium SUV (4WD)	Minivan	½-Ton Pickup (4WD)	Hybrid Vehicle	Electric Vehicle
Maintenance Cost	6.83	7.94	8.44	8.09	8.27	7.81	8.33	6.99	6.55
EMFAC Vehicle Class	LDA[1]	LDA[1]	LDA[1]	LDT1	LDT2[1]	LDT2[1]	MDV	Hybrid Vehicle	Electric Vehicle
Maintenance Cost	7.74	7.74	7.74	8.09	8.04	8.04	8.33	6.99	6.55

[1] Where multiple AAA vehicle categories were assigned to a single EMFAC vehicle classification, an average maintenance cost for the EMFAC vehicle classification was calculated from the AAA vehicle category maintenance costs.

In the absence of diesel data, CARB conservatively assumed diesel and gasoline costs were the same, as diesel with a higher energy efficiency than gasoline would be anticipated to have lower fuel costs for diesel on a per-unit basis. All 2017 maintenance costs (2017 dollar values) were held constant for post-2017 years, as adjustments for future economy are not available. For historical years, AAA maintenance costs were

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[24] American Automobile Association. *Your Driving Cost: How much are you really paying to drive?* 2017 Edition. Available at: https://exchange.aaa.com/wp-content/uploads/2017/08/17-0013_Your-Driving-Costs-Brochure-2017-FNL-CX-1.pdf.

converted to $2017 dollars. AAA only provides a single value for electric vehicles, and a single value for hybrid vehicles, so those values were applied without this adjustment.

CARB converted AAA vehicle classes into the four equivalent EMFAC LDV vehicle classes (LDA, LDT1, LDT2, and MDV) as follows:[25]

- The three AAA sedan categories (small, medium, and large sedan) were classified as the LDA EMFAC vehicle class.
- The AAA Small SUV category was classified as the T1 light-duty truck (LDT1), trucks with a GVWR < 3,751 pounds, EMFAC vehicle class.
- The AAA medium SUV and minivan categories were classified as the T2 light-duty truck (LDT2), trucks with a GVWR from 3,751 pounds to 5,750 pounds, EMFAC vehicle class.
- The AAA half-ton pickup category was classified as the Medium Duty Vehicle (MDV), trucks with a GVWR from 6,000 pounds to 8,500 pounds, EMFAC vehicle class.

Table 11 provides calendar year 2017 default EMFAC2017 VMT for the four LDV classes (LDA, LDT1, LDT2, and MDV) and the percentage each class represents of the total LDV VMT.

[25] Where multiple AAA vehicle categories were assigned to a single EMFAC vehicle classification, an average maintenance cost for the EMFAC vehicle classification was calculated from the AAA vehicle category maintenance costs.

Table 11. Default EMFAC2017 Vehicle Classes VMT and Percentage of Total for Calendar Year 2017

	VMT				Percent of Total			
MPO	LDA	LDT1	LDT2	MDV	LDA	LDT1	LDT2	MDV
AMBAG	9,168,211	919,497	3,833,045	3,248,960	53.4%	5.4%	22.3%	18.9%
BCAG	2,465,099	329,216	1,223,106	1,009,204	49.0%	6.5%	24.3%	20.1%
FCOG	12,567,427	1,273,463	4,636,514	4,677,647	54.3%	5.5%	20.0%	20.2%
KCAG	2,712,370	245,154	871,077	1,037,968	55.7%	5.0%	17.9%	21.3%
KCOG	13,680,964	1,388,831	5,106,643	5,585,076	53.1%	5.4%	19.8%	21.7%
MCAG	3,811,882	344,475	1,216,982	1,388,863	56.4%	5.1%	18.0%	20.5%
MCTC	2,411,316	253,412	922,496	962,360	53.0%	5.6%	20.3%	21.2%
MTC/ABAG	95,245,678	9,616,302	33,125,608	20,598,552	60.1%	6.1%	20.9%	13.0%
SACOG	31,141,404	3,432,694	11,993,566	9,260,796	55.8%	6.1%	21.5%	16.6%
SANDAG	50,899,724	5,884,823	18,916,838	12,349,369	57.8%	6.7%	21.5%	14.0%
SBCAG	5,204,353	513,203	2,269,960	1,803,362	53.2%	5.2%	23.2%	18.4%
SCAG	284,004,628	27,646,702	93,952,775	67,138,580	60.1%	5.8%	19.9%	14.2%
SRTA	3,241,673	361,127	1,415,920	1,178,899	52.3%	5.8%	22.8%	19.0%
SJCOG	10,288,434	939,520	3,270,371	3,308,621	57.8%	5.3%	18.4%	18.6%
SLOCOG	4,440,860	507,115	1,987,769	1,561,560	52.3%	6.0%	23.4%	18.4%
StanCOG	7,449,173	731,661	2,524,477	2,798,539	55.2%	5.4%	18.7%	20.7%
TCAG	6,600,673	655,563	2,291,123	2,952,239	52.8%	5.2%	18.3%	23.6%
TMPO	291,772	69,176	302,950	192,099	34.1%	8.1%	35.4%	22.4%
Statewide	**562,962,051**	**57,737,620**	**198,210,410**	**147,833,940**	**58.2%**	**6.0%**	**20.5%**	**15.3%**

Using the AAA year 2017 maintenance cost data from **Table 10** and VMT percentage by LDV class (LDA, LDT1, LDT2, and MDV) data from **Table 11**, **Table 12** presents composite calendar year 2017 LDV maintenance costs (cents per mile) calculated for each MPO. The vehicle classes summarized in **Table 12** include LDV class (LDA, LDT1, LDT2, and MDV) weighted by VMT, hybrid vehicles, and electric vehicles. As maintenance costs vary by category/vehicle class (e.g., sedan/LDA, SUV/LDT1, minivan/LDT2, etc.), this approach provides a more accurate estimate of an MPO's LDV fleet maintenance cost.

Table 12. AAA Calendar Year 2017 Vehicle Maintenance Costs (cents per mile)

MPO	LDV Class (LDA, LDT1, LDT2, and MDV	Hybrid Vehicles	Electric Vehicles
AMBAG	7.94	6.55	6.99
BCAG	7.95	6.55	6.99
FCOG	7.94	6.55	6.99
KCAG	7.94	6.55	6.99
KCOG	7.94	6.55	6.99
MCAG	7.93	6.55	6.99
MCTC	7.94	6.55	6.99
MTC/ABAG	7.90	6.55	6.99
SACOG	7.92	6.55	6.99
SANDAG	7.91	6.55	6.99
SBCAG	7.93	6.55	6.99
SCAG	7.90	6.55	6.99
SRTA	7.94	6.55	6.99
SJCOG	7.92	6.55	6.99
SLOCOG	7.94	6.55	6.99
StanCOG	7.94	6.55	6.99
TCAG	7.95	6.55	6.99
TMPO	8.01	6.55	6.99
Statewide	7.91	6.55	6.99

The LDV class values are weighted by the LDA, LDT1, LDT2, and MDV VMT percentages presented in **Table 11**.

Auto Operating Cost

AOC is the sum of fuel and MRT costs (in cents per mile), each vehicle and technology/fuel type. To estimate an aggregate AOC for all LDV, CARB used a VMT-weighted approach where each fuel's AOC was multiplied by its VMT percentage of total VMT. In this case, EMFAC2017 VMT, specific to each fuel and MPO, was used to determine the VMT-weighting factors.

Auto Operating Cost Tool Directions

Detailed step-by-step instructions to estimate AOC using the AOC Calculator tool, available for download from the California Air Resources Board's website site at: https://ww2.arb.ca.gov/resources/documents/scs-evaluation-resources, is as follows:

Step 1: Navigate to the "Calc" tab and select an MPO and Calendar Year from the drop-down lists. To avoid AOC Calculator tool malfunction, users should <u>not</u> type in the MPO name nor Calendar year. Instead, use the MPO drop-down list that includes all 18 MPOs, and the Calendar Year drop-down list that includes all calendar years from 2000 to 2050.

Select MPO	AMBAG
Select Calendar Year	2005

Step 2: The AOC Calculator tool will automatically update the fuel price for each fuel, based on the Calendar Year selected in Step 1, which uses the [insert vintage year] CEC fuel price data.

Select MPO	AMBAG
Select Calendar Year	2005

	GASOLINE			DIESEL			ELECTRIC			HYDROGEN			PHEV		
		Value			Value			Value			Value			Value	
	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom
Fuel Cost (dollar/gasoline gallon equivalent)[1]	Default	3.11		Default	3.22		Default	4.83		Default	13.99			N/A	N/A
Non-fuel Cost (cents per mile) [2]	Default	6.49		Default	6.49		Default	5.36		Default	6.49			5.72	5.72
VMT	Default	15,455,046		Default	64,702		Default	5,101		Default	-		Default	-	

Users can input an alternative fuel price using the custom mode by selecting “Custom” from the drop-down list in the “Data Source” column and then entering in the MPO-specific fuel price data in the “Custom” column.

Select MPO	AMBAG
Select Calendar Year	2005

	GASOLINE			DIESEL			ELECTRIC			HYDROGEN			PHEV		
		Value			Value			Value			Value			Value	
	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom
Fuel Cost (dollar/gasoline gallon equivalent)[1]	Custom		3.00	Custom		3.50	Custom		5.00	Custom		14.00		N/A	N/A
Non-fuel Cost (cents per mile) [2]	Default	6.49		Default	6.49		Default	5.36		Default	6.49			5.72	5.72
VMT	Default	15,455,046		Default	64,702		Default	5,101		Default	-		Default	-	

Step 3: The AOC Calculator tool will automatically update the default non-fuel cost (maintenance, repair and tire cost) for each fuel, based on the Calendar Year selected, using the most recent AAA report. Users can input alternative non-fuel cost using the custom mode by selecting "Custom" from the drop-down list in the "Data Source" column and then entering in MPO-specific non-fuel price data in the "Custom" column.

Select MPO	AMBAG
Select Calendar Year	2005

	GASOLINE			DIESEL			ELECTRIC			HYDROGEN			PHEV		
		Value			Value			Value			Value			Value	
	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom
Fuel Cost (dollar/gasoline gallon equivalent)[1]	Default	3.11		Default	3.22		Default	4.83		Default	13.99			N/A	N/A
Non-fuel Cost (cents per mile)[2]	Custom		7.00	Custom		7.00	Custom		5.50	Custom		6.50		5.72	5.72
VMT	Default	15,455,046		Default	64,702		Default	5,101		Default	-		Default	-	

Step 4: Enter the LDV VMT by fuel type from the travel demand model for a given MPO by selecting "Custom" from the drop-down list in the "Data Source" column and then entering in MPO-specific LDV VMT data in the "Custom" column. If users do not provide this information, the AOC Calculator tool will use default EMFAC2017 VMT.

Select MPO	AMBAG
Select Calendar Year	2005

	GASOLINE			DIESEL			ELECTRIC			HYDROGEN		
		Value			Value			Value			Value	
	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom
Fuel Cost (dollar/gasoline gallon equivalent)[1]	Default	3.11		Default	3.22		Default	4.83		Default	13.99	
Non-fuel Cost (cents per mile)[2]	Custom		7.00	Custom		7.00	Custom		5.50	Custom		6.50
VMT	Custom		15455046	Custom		64700	Custom		5200	Default	-	

Step 5: Utilizing the fuel and non-fuel costs, the AOC Calculator tool calculates the AOC (cents per mile) by fuel type. Based on the calculated AOC by fuel type, a total VMT-weighted fleet AOC (cents per mile) that combines each fuel's total cost per mile for fuel and non-fuel costs is calculated. The AOC Calculator tool will also auto-populate the fuel efficiencies by fuel type.

Select MPO	AMBAG
Select Calendar Year	2005

	GASOLINE			DIESEL			ELECTRIC			HYDROGEN		
		Value			Value			Value			Value	
	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom
Fuel Cost (dollar/gasoline gallon equivalent)[1]	Default	3.11		Default	3.22		Default	4.83		Default	13.99	
Non-fuel Cost (cents per mile)[2]	Custom		7.00	Custom		7.00	Custom		5.50	Custom		6.50
VMT	Custom		15455046	Custom		64700	Custom		5200	Default	-	
Fuel Efficiency (mile/gasoline gallon equivulent)	Gasoline	19.67		Diesel	28.14		Electric	100.38		Hydrogen	-	
Auto Operating Cost by Fuel Type (Cents/Mile)	Gasoline	22.82		Diesel	18.46		Electric	10.32		Hydrogen	6.50	

Step 6: Once a specific analysis run with the AOC Calculator tool is complete the use can select the "Record This Run" button, and all inputs and the corresponding results of the analysis run will be recorded in the "Report Sheet" to be submitted to CARB for review.

Auto Operation Cost Calculator Report Sheet

Calendar Year	Technology	Fuel Cost	Non-Fuel Cost	VMT	Calculated AOC
2005	Gasoline	3.112	7.000	15455046	22.80
	Diesel	3.225	7.000	64700	
	Electric	4.834	5.500	5200	
	Hydrogen	13.993	6.500	0	

Step 7: To start a new analysis run or to clear custom data, click the "Set to Default" button in the "Calc" tab and all custom input info will be cleared, and the user can start a new run.

Calendar Year	2035
Auto Operating Cost (Cents/Mile)	18.92

Record This Run

Set to Default

Step 8: The "Report Sheet" can store up to five records. If the spreadsheet reaches maximum storage and user wants to clear all stored records, please click the "Clear All Record" button on the "Calc" tab.

Select MPO	SCAG
Select Calendar Year	2035

Clear All Record

	GASOLINE			DIESEL			ELECTRIC			HYDROGEN			PHEV		
		Value			Value			Value			Value			Value	
	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom	Data Source	Default	Custom
Fuel Cost (dollar/gasoline gallon equivalent)[1]	Default	4.18		Default	4.16		Default	6.61		Default	10.32			5.54	5.54
Non-fuel Cost (cents per mile)[2]	Default	7.90		Default	7.90		Default	7.90		Default	7.90			6.99	6.99
VMT	Default	494,312,564		Default	6,903,809		Default	8,848,253		Default	4,690,034		Default	18,275,379	
Fuel Efficiency (mile/gasoline gallon equivlent)	Gasoline	36.82		Diesel	48.32		Electric	135.64		Hydrogen	88.65		PHEV	76.28	
Auto Operating Cost by Fuel Type (Cents/Mile)	Gasoline	19.25		Diesel	16.51		Electric	12.77		Hydrogen	19.55		PHEV	13.47	

Calendar Year	2035
Auto Operating Cost (Cents/Mile)	18.92

Record This Run

Set to Default

Note 1. Default LDV population, VMT, and fuel usage data was obtained from the EMFAC2017 model. However, the Vision model was used to distribute outputs for electric, hydrogen, and PHEV vehicles, as EMFAC2017 does not provide any output for hydrogen nor hybrid vehicles, and does not provide fuel usage output for electric vehicles. The EMFAC and Vision output data includes calendar year, GAI (MPO), vehicle class, fuel type, population, VMT, trips, and fuel use. Population, VMT, trips, and fuel use are further divided into internal combustion engine (ICE) and electric categories.

Note 2. CEC provided the most currently available fuel cost data for gasoline, diesel, hydrogen, and electricity for various years, while historical and future years costs were adjusted for inflation from the data provided by CEC:

- Gasoline and diesel fuel
  - CEC provided historical prices for the years 2000 to 2017 and projected prices for the years 2018 to 2030
  - Prices for the years 2031 to 2050 were increased by 1.69% per year to adjust for inflation.
- Hydrogen fuel and electricity
  - CEC provided prices for the years 2015 to 2030
  - To adjust for inflation, prices for the years 2000 to 2014 were decreased by 1.69% per year and prices for the years 2031 to 2050 were increased by 1.69% per year to adjust for inflation.
- Fuel costs were provided by CEC in 2015 dollars in dollars per GGE for all fuels except diesel, which was provided in dollars per diesel gallon equivalent (DGE). CEC provided a conversion factor (0.86) to convert dollars per DGE to dollars per GGE, and a conversion factor (1.034, or 1.69% per year) to convert from 2015 dollars to 2017 dollars. The same adjustment factor (i.e., 1.69% per year) was applied to future and past years to adjust for inflation.

Note 3. Costs for non-fuel costs (i.e., maintenance, repair, and tires) were obtained from AAA in 2017 values. Because AAA data prior to 2017 did not include light trucks, electric, nor hybrid vehicles, pre-2017 year data from AAA was not used. The AAA data classified vehicles as sedan (small, medium, and large), SUV (small and medium), minivan, ½-ton light truck, hybrid vehicle, and electric vehicle. The AAA costs were calculated specific to each MPO by applying the default EMFAC2017 light-duty vehicle VMT distributions by vehicle class found in **Table 11**.[26]

Future Research

Existing literature extensively documents the impact of fuel price on VMT and travel behavior, whereas the impact of other non-fuel operating costs on VMT are very limited. According to AAA, other non-fuel costs (e.g. depreciation, insurance, license fees, taxes, and registration) account for more than 70% of the costs of owning and operating

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[26] American Automobile Association. *Your Driving Cost: How much are you really paying to drive?* 2017 Edition. Available at: https://exchange.aaa.com/wp-content/uploads/2017/08/17-0013_Your-Driving-Costs-Brochure-2017-FNL-CX-1.pdf.

a vehicle. In the near future, a further study should be conducted to better understand the impact of these costs on VMT and travel behavior.

Reporting Interregional Travel

MPOs use travel demand models to estimate the regional VMT and its associated GHG emissions used in SB 375 GHG emission reduction target demonstrations. In the travel demand model, trips are classified into Internal-Internal (II) trips, Internal-External (IX) or External-Internal (XI) trips, and External-External (XX) trips, depending on the origin and destination points. Trips that have an origin or destination point outside of the MPO region are considered "interregional". During the original SB 375 GHG emission reduction target setting process that occurred in 2010, the Regional Targets Advisory Committee (RTAC) recommended that MPOs include 100 percent of the VMT associated with II trips, and 50 percent of VMT associated with IX and XI trips in its demonstration of SB 375 GHG emission reduction target achievement. The RTAC recommended that VMT associated with XX trips be excluded because an MPO has little control over trips that have no origin or destination point in (i.e., "pass through") the region.[27] Due to geographic limitations of many travel demand models, this reporting framework results in the truncation of trip distances for IX and XI interregional trips. For this reason, CARB staff agreed that MPOs should include 100 percent of IX and XI VMT up to the travel demand model boundary in its accounting of VMT used in SB 375 GHG emission reduction target demonstrations, and most MPOs have been using this framework in previous *SCS Evaluation Staff Reports*.

CARB staff recommends that MPOs include 100 percent of the VMT associated with II, XI, and IX trips up to the travel demand model's boundary when estimating the VMT used in SB 375 GHG emission reduction GHG emission reduction target achievement. CARB staff still recommends that MPOs exclude all VMT associated with XX trips.

Submitting SCS to CARB for Review

This section proposes a standardized template for MPOs to use for the SCS submittal to CARB. This is submitted to CARB by the MPO once the RTP/SCS has been adopted to provide CARB staff with the materials needed to initiate the evaluation. The list provided below serve as a checklist for MPOs as they prepare SCS submittals and help improve consistency among MPO SCS submittals and clearly present the information

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[27] Regional Targets Advisory Committee. *Recommendations of the Regional Targets Advisory Committee (RTAC) Pursuant to Senate Bill 375: A Report to the California Air Resources Board*. September 2009. Available at: https://www.arb.ca.gov/cc/sb375/rtac/report/092909/finalreport.pdf.

needed for CARB to begin the evaluation, thus minimizing questions regarding what is required for the evaluation.

- Digital copy or hyperlink to your Adopted RTP/SCS Document.
- Documentation of what land use and transportation strategies are being claimed for credit toward your targets, which are quantified via your Travel Demand Model vs Off-Model, and indication of which if any are new compared to your previously adopted plan
- Completed SB 375 Data Table (2018 version)
- Copy or hyperlink to your Travel Demand Model Documentation
- Copy or hyperlink to any Off-Model Calculations and Assumptions
- EMFAC Input and Output Files
- Documentation of your EMFAC Adjustment Calculation
- Travel Demand Model Sensitivity Test Results (If needed, as determined by CARB staff.)

Appendix E: Quantifying Greenhouse Gas Emission Reductions from Off-Model Strategies

MPOs have identified the inherent limitations in the travel demand models and the need for quantifying GHG emission reductions from some RTP/SCS strategies, known as off-model strategies,[28] outside of travel demand models. The methods to estimate GHG emission reductions from these off-model RTP/SCS strategies are based on evidence from empirical data and research.

An MPO's travel demand model cannot capture the contributions from strategies toward the SB 375 GHG emission reduction targets when:

- The travel demand model is not sufficiently sensitive to the particular strategy or variables associated with the strategy;
- The strategy reduces GHG emissions from passenger vehicles through means other than reducing VMT.

CARB's existing SCS Evaluation guidance from 2011 does not provide explicit guidance for use of off-model strategies. Since the adoption of the first set of SB 375 GHG emission reduction targets in 2010, CARB has conducted over 25 SCS Evaluations, many of which include off-model strategies proposed by MPOs. In conducting these SCS Evaluations, CARB staff has observed a wide variety of approaches and varying levels of complexity in estimating off-model GHG emission reductions from the same type of strategy. These differences in approaches have varied widely depending upon the availability of MPO resources (e.g., staffing, funding, and schedule), datasets, and other related information about strategies. For example, some MPOs collect region-specific data and develop spreadsheet tools to manually estimate GHG emission reductions from a strategy, whereas other MPOs may estimate GHG emission reductions based on elasticities from empirical literature for the same type of strategy. In some instances, MPOs report the same GHG emission reduction from another MPO without taking into consideration local conditions.

Purpose and Goals of Off-Model Strategy Guidance

Taking lessons learned based on CARB's previous SCS Evaluations, as well as from researching the current state of practice, CARB staff is providing MPOs detailed guidance for the quantification of off-model strategies. Specifically, the purpose and goals of the off-model guidance is to:

[28] For the purposes of this Guidance, off-model strategies are travel demand management and vehicle technology-based GHG emissions reduction strategies that are not included and evaluated within an MPO's travel demand model.

- Identify common consistent approaches for MPOs to quantify GHG emission reductions from off-model strategies by outlining the key technical aspects and level of detail that underlie GHG quantification and methodologies;
- Clarify expectations around level of detail and resolution of data that should be used by MPOs to quantify GHG emission reductions from off-model strategies;
- Enhance the accountability and transparency of how the MPOs quantify GHG emission reductions from off-model strategies;
- Engage MPOs to exchange knowledge and methods to promote best practices on modeling GHG benefits from off-model strategies;
- Begin tracking progress on the effectiveness and implementation off-model strategies.[29]

CARB staff anticipates the off-model guidance will improve efficiency and defensibility of the documentation needed to calculate the GHG emission reduction benefits of off-model strategies. Off-model strategy guidance also serves to provide MPOs with additional transparency, clarity, and level of detail to better align the MPO's development and quantification of off-model strategies with CARB's SCS Evaluation Process. These sample quantification methods are available for use by MPOs, however strictly adhering to the methods suggested in this appendix is not mandatory.

For off-model strategies not specifically covered in this guidance, or if MPOs have an alternative approach to quantifying GHG emission reduction benefits from an off-model strategy, the MPO must document the methodology, assumptions, and datasets, in addition to demonstrating how each component of the off-model framework from the guidance is addressed and satisfied. If an MPO elects to implement a strategy and quantification methodology based on a strategy currently employed by another MPO(s), the MPO must cite all the applicable resources and demonstrate why the methodology and any assumptions borrowed from another MPO applies. Further, MPO should document in its Technical Methodology submittal to CARB (see **Appendix A**) why a given strategy is not reflected in its travel demand modeling and why an off-model quantification approach is appropriate for a given strategy.

If an MPO includes an off-model strategy as part of its RTP/SCS, the MPO should continue to quantify the GHG emissions reduction benefits of that off-model strategy in all future RTP/SCSs. If the MPO is no longer implementing the off-model strategy, the MPO should document the termination of that off-model strategy in the Technical Methodology submittal. If the off-model strategy is now reflected in the travel demand

[29] Tracking strategy implementation does not assign a rating, scoring, or ranking of an MPO's success with implementation of an off-model SCS strategy. Rather, tracking strategy implementation serves to verify whether a strategy from an SCS has been implemented.

modeling due to model upgrades or improved model sensitivity, the MPO should document plans to rely on the travel demand model output to quantify the GHG emissions reduction benefit of that strategy, and it will no longer be quantified off-model.

Off-Model Evaluation

Based on the purpose and goals indicated above, CARB has prepared an off-model evaluation framework that consists of five components MPOs should consider, at a minimum, when developing and quantifying an off-model strategy:

1) *Strategy Description:* Describes the overall off-model strategy
2) *Objectives:* How the off-model strategy would reduce GHG emissions
3) *Trip and Emissions Data Needs:* A question-based approach to help identify the types of data needed to quantify off-model GHG emission reductions
4) *Quantification Methodology:* Steps and assumptions for quantifying GHG emission reductions
5) *Challenges, Constraints, and Strategy Implementation Tracking:* Challenges MPOs may face when quantifying and implementing off-model strategies, as well as how the MPO plans to track if strategies are working and whether course corrections to strategies are necessary to get a region back on track towards meeting its GHG emission reduction goals

How does CARB use this data?

As part of CARB's SCS Evaluation Process, CARB staff will evaluate an MPO's responses to each of the five components to assist with the determination whether the SCS appropriately documents the development, quantification, and effectiveness and potential adjustments of the MPO's off-model strategies. CARB staff needs this level of detail to demonstrate that the quantification of GHG emission reductions from off-model strategies are quantifiable, surplus to existing state programs, are feasible through 2035, and can be tracked and monitored for successful implementation. This level of substantiation is necessary to give CARB staff the confidence that the associated GHG emission reduction benefits are reasonably likely to occur in the appropriate timeframe, and are truly additional to GHG emission reductions already quantified through the MPO's travel demand modeling, or surplus to existing state programs.

Strategy Description

CARB staff expects MPOs to document and provide evidence that the regional travel demand model is not sensitive to the given strategy, and why an off-model calculation is warranted for quantification. The strategy description should clearly state the MPO's plan, program, or project(s) that will reduce GHG emissions.

Objectives

The objective section of this framework should identify how the given strategy would impact travel activities or characteristics that will result in GHG emission reductions.

Trip and Emissions Data Needs

The questions listed for the *Trip and Emissions Data Needs* category in **Table 13** are general questions designed to solicit key data points used by the MPO to quantify GHG emission reductions from off-model strategies, and document those key data points for CARB. The MPO must report on funding commitments (if known), current and future levels of deployment, the targeted population affected by the strategy, and responsible parties for implementation and tracking. This information is necessary to determine the scope and the scale of the strategy, and its applicability within the region. Additional detailed data specific to the individual quantification method for each strategy are listed in the individual strategy discussions in the subsequent sections that follow.

Funding commitments for every off-model strategy (if known/available) should be clearly documented including the source and timing of the funding. MPOs may not take credit for an off-model strategy if the strategy is already counted towards statewide GHG emission reductions assumed in CARB's *2030 Scoping Plan Update*[30] prepared pursuant to AB 32 and SB 32. GHG emission reductions from an off-model strategy must be surplus and additional with respect to *Scoping Plan* accounting. CARB staff can advise the MPO on whether GHG emission reductions from a given strategy meet these criteria. To avoid double counting of GHG emission reductions, an MPO must demonstrate that its investments and implementation of a program are surplus and additional and not a result of existing modeling tools or mandated by a currently adopted plan or regulation, then the MPO may take credit for the off-model strategy. For example, MPOs may not take GHG emission reduction credit from State-sponsored programs in support of meeting statewide targets for ZEV sales (e.g., ZEV incentive

[30] California Air Resources Board. *California's 2017 Climate Change Scoping Plan: The Strategy for Achieving California's 2030 Greenhouse Gas Target*. November 2017. Available at: https://www.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf.

funding from the CPUC), as these programs and associated GHG emission reductions are already fully accounted for in the *Scoping Plan* toward meeting State climate goals. Further, MPOs may not take off-model GHG emission reduction credit from programs or projects intended to mitigate impacts that have already occurred (e.g., funding resulting from the Volkswagen Settlement Agreement or mitigation resulting from projects subject to the California Environmental Quality Act). However, an MPO may take credit for EV charging infrastructure funded through local or regional funding sources when the MPO can demonstrate that accelerated ZEV deployment would occur above-and-beyond State programs or existing requirements. An MPO may rightfully incorporate land use planning around any planned high speed rail stations into its travel demand model, and any VMT and GHG emission reductions directly attributable to those land use planning assumptions should be reflected in the MPO's travel demand model output.

Quantification Methodology

This section should document the steps and the calculations the MPO followed to arrive at the estimated GHG emission reductions from the strategy, including how the trip and emissions data needs were reflected in the calculations.

Challenges, Constraints, and Strategy Implementation Tracking

This section should provide commentary on challenges and constraints that the MPO considered when estimating the benefits of the off-model strategy, and how those challenges and constraints are reflected in the estimate of GHG emission reduction benefits (e.g., whether more conservative assumptions were applied). This section should also describe how the success of the strategy will be monitored and verified. Once an off-model strategy is incorporated into an SCS, the MPO should continue to track and monitor the progress of a given strategy in subsequent SCSs.

Table 13 below describes the five components that comprise the off-model evaluation framework in further detail. The off-model evaluation framework provides MPOs with the potential variables and methodologies MPOs should consider when developing and quantifying off-model strategies that is consistent with CARB's SCS Evaluation Process.

Table 13. Off-Model Strategy Evaluation

Off-Model Strategy Component	Description of Off-Model Strategy

Strategy Description	• Describe the overall off-model strategy
	  ◦ Identify what the strategy implements
	  ◦ Identify how the strategy reduces CO_2 emissions
	  ◦ Identify how the strategy is not already reflected in land use and travel modeling tools, thus warranting an off-model estimate of CO_2 emission reductions.

Objectives	• Identify the specific metric(s) targeted and changed by the off-model strategy that would result in CO_2 emission reductions. Examples include, but not limited to:
	  ◦ Decreased VMT/average trip length
	  ◦ Miles of bike/pedestrian lanes added
	  ◦ Reduced vehicle trips
	  ◦ Traffic flow improvements
	  ◦ Increased transit boardings

Trip and Emissions Data Needs[1]	This question-based approach (six categories) will help to identify data that may be required to quantify and track strategy:
	
	Funding/Incentives
	• How much funding is identified for implementing the strategy?
	• What is/are the source(s) of funding for implementing the strategy?
	
	Current Level of Deployment
	• What is the existing and planned scope of the strategy?
	• Is the strategy already in use?
	• What is the current participation rate of the strategy?
	
	Future Level of Deployment
	• What is the goal participation rate for the strategy?
	• Is the strategy surplus/additional (e.g., goes beyond existing State programs)?
	• What metrics must be tracked and met to demonstrate strategy implementation?
	• How will strategy implementation and metrics be tracked?
	• When would the strategy be implemented and when would it end?
	
	Responsible Parties
	• Who will administer the program?
	• Who will track strategy implementation and metrics?
	
	Affected Population
	• Who is the population being targeted by the strategy?
	    ▪ Specific cohorts (e.g., industry type, user type, etc.)?
	    ▪ Specific geographic areas (e.g., MPO-wide, specific area, specific land use, specific density)?
	
	Trip and Emissions Data
	• What specific data is needed to quantify CO_2 emission reductions from the strategy? See Example Quantification Methodologies Section.

Off-Model Strategy Component	Description of Off-Model Strategy
Quantification Methodology[2]	• Describe methodology for quantifying CO_2 emission reductions from the strategy • Base methodology on empirical evidence supported by verifiable data sources • Clearly describe and document individual steps in emission calculations • Clearly document all assumptions, sources of data, and calculations
Challenges, Constraints, and Strategy Implementation Tracking	• Potential challenges and constraints with quantifying and implementing off-model strategies • Define and collect "Metrics of Success"[3] that the MPO plans to collect to track whether a strategy is successfully implemented over time

Notes:
[1] Questions listed in the *Trip and Emissions Data Needs* component are general questions MPOs should address and answer in the SCS and in the SCS data submittal to CARB. *Trip and Emissions Data Needs* applicable to a specific strategy are listed in the individual strategy discussions in the next sections below. As part of CARB's SCS Evaluation Process, CARB staff will evaluate an MPO's responses to the *Trip and Emissions Data Needs* questions to assist with CARB's SCS determination whether the SCS appropriately documents the development, quantification, and future implementation of the MPO's off-model strategies.
[2] See subsequent section for examples of quantification methods for select strategies. For strategies that are not specifically covered in these guidelines, or if MPOs have an alternative approach to quantifying GHG benefits, the MPO should document its own specific methodology and demonstrate how each component of the off-model framework is addressed and satisfied. Methodology should be presented in a linear and step-wise manner allowing CARB staff to follow how key variables and calculations are used to estimate GHG emission reductions.
[3] "Metrics of Success" are metrics that verify a strategy is successfully implemented. Responses to *Trip and Emissions Data Needs* questions frame and identify "Metrics of Success" the off-model strategy.

Example Quantification Methodologies

The previous section provides an overall framework for developing, quantifying, and tracking off-model strategies. The following section contains sample quantification methodologies that are acceptable to CARB staff for estimating GHG emission reductions from select off-model strategies.

The following strategies commonly quantified off-model by MPOs are discussed within its own separate section of this guidance.

- Transit improvements
- Bicycle and Pedestrian Facility Enhancement
- Bike Share
- Telecommuting/Work-At-Home
- Car Sharing
- Electric Vehicle Charging Infrastructure
- Parking Management
- Electric Vehicle Incentives
- Transportation System Management (TSM)/Intelligent Transportation Systems (ITS)
- Vanpool

Transit Improvements

Strategy Description

Transit improvement strategies generally decrease private automobile trips by increasing bus, subway, and train (both heavy and light-rail) ridership. Typically, ridership increases are associated with establishing new routes, increasing transit frequency (headway) and/or expanding transit service daily hours of operation. The targeted population for this strategy is commuters who use single-occupancy vehicles for commute purposes. **Table 14** provides an example of both infrastructure projects and non-infrastructure transit projects.

Table 14. Off-Model Strategy Evaluation

Transit Infrastructure Project(s)	Non-Infrastructure Project(s)
• Construction of new transit routes • Extension of existing transit routes (decreasing transit headway and/or expanding transit service daily hours of operation) • Complete streets (e.g. transit only lanes, bus stops, bus shelters) • Installation of signage • Provide transit parking, bicycle lockers, or equipment to modify transit vehicles to accommodate bikes (e.g. bus bike racks) • Bike sharing programs at transit stations	• Service and frequency increases • Fare reductions

Objectives

Transit improvement strategies can reduce GHG emissions as follows:

- Single-occupancy VMT displaced by transit
- Increased transit boardings/ridership
- Increased transit service hours
- Increased transit lane miles

Trip and Emissions Data Needs

In addition to the general input data and assumptions for off-model strategies listed in **Table 13** of the introduction section, the following is a list of specific conditions and factors that MPOs should consider and document for transit strategies:

- Is the strategy aimed at solely increasing transit, or are other benefits (e.g., facilitating walking and bicycle use) anticipated as part of the strategy?
- Average HW trip length (miles/trip)

Quantification Methodology

The basic analytical steps that MPOs should consider when estimating GHG emission reductions associated with transit improvement strategies.

Typically, CO_2 emission reductions from transit strategies are a result of VMT reductions due to mode shift from private automobile trips to transit:

$$Transit\ Strategy \rightarrow Transit\ Ridership\ Increase \rightarrow VMT\ Reduction \rightarrow CO_2\ Reduction$$

The overall approach is to determine the increase in transit ridership, estimating the mode shift from private automobile to transit, estimating average trip lengths for the region, obtaining necessary emission rates, and estimating net emissions associated with decreased private automobile use and increased transit activity (if applicable). Where available, region-specific data should be used in place of values listed herein.

Step 1: Identify baseline regional transit ridership using data from regional and/or local transit operators.

Step 2: Evaluate percent increase in transit ridership from baseline associated with strategy.

a) Preferred Approach: Use data from regional and/or local transit operators, region-specific study, or other empirical data sources.
b) Alternate Approach: Use most conservative values listed in Table 2[31] from CARB *Impacts of Transit Service Strategies on Passenger Vehicle Use andGreenhouse Gas Emissions: Policy Brief*[32] document.

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[31] Handy, S., Lovejoy, K., Boarnet, M., & Spears, S. *Impacts of Transit Service Strategies On Passenger Vehicle Use and Greenhouse Gas Emissions October 2013.* Available at: https://www.arb.ca.gov/cc/sb375/policies/transitservice/transit_brief.pdf.

[32] The data presented in the California Air Resources Board transit service policy brief includes meta-analyses of a large number of studies (including a large sample of U.S. transit systems) that statistically accounts for the characteristics of the different transit systems evaluated.

Step 3: Estimate Mode Shift Factor for shift in trips from private automobile trips to transit[33, 34]

a) Preferred Approach: Use mode shift data from region-specific travel demand model analysis (i.e., remove transit network from travel demand model and estimate VMT associated with removal of the transit network).
b) Alternate Approach 1: Use region-specific survey data from regional and/or local transit operators.
c) Alternate Approach 2: Use applicable mode shift factors from the American Public Transportation Association's (APTA) *Quantifying Greenhouse Gas Emissions from Transit*[35,36] based on transit agency regional service area type (size of population served) (see Column G from **Table 15)**. In the event an MPO has region-specific data for the variables listed in **Table 15**, a region-specific Mode Shift Factor may be calculated using the formula provided in Column G of **Table 15**.

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[33] The mode shift factor is a ratio of displaced private automobile miles to transit passenger miles and is indicative the percentage of trips by mode that would have been taken if transit service is not available. It is assumed that transit and displaced private automobile trips are equal in length and one transit trip equals one private automobile trip.

[34] American Public Transportation Association. APTA Standards Development Program Recommended Practice. *Quantifying Greenhouse Gas Emissions from Transit*. APTA SUDS-CC-RP-001-09. August 2009. Available at: https://www.apta.com/resources/standards/Documents/APTA%20SUDS%20CC-RP-001-09_Rev%201.pdf.

[35] Ibid.

[36] The data presented in the APTA study includes studies evaluating urbanized and metro areas, including land use effects caused by transit.

Table 15. Transit Alternative Modes of Travel Choices[37]

Service Area Type and Population	Drive Alone	Walk	Ride with Someone	Taxi	Bicycle	Not Make Trip	Mode Shift Factor
	A	B	C	D	E	F	G A + D + (C / 2.5)
All Systems	24.0%	17.7%	21.6%	11.6%	3.7%	21.4%	0.44
Small < 500,000	12.8%	26.8%	22.8%	11.7%	4.5%	21.5%	0.34
Medium 500,000 to 1,250,000	21.1%	22.0%	20.0%	13.1%	5.1%	18.7%	0.42
Large > 1,250,000	24.9%	7.0%	33.1%	8.7%	1.1%	25.2%	0.47
Large Suburban > 1,250,000	14.5%	16.7%	22.9%	20.6%	2.4%	22.8%	0.44

Step 4: Estimate Land Use Multiplier.[38, 39]

a) Preferred Approach: Use data from region-specific travel demand model analysis, region-specific study, or other empirical data sources.

b) Alternate Approach: Use national default multiplier of 1.9.[40]

Step 5: Estimate average vehicle occupancy (AVO) for displaced private automobile trips.

a) Preferred Approach: Use region-specific travel demand model AVO assumptions.

[37] Indicates the percentage of trips by mode that would have been taken when transit service is not available.

[38] The land use multiplier is a unitless reduction factor (Vehicle-mile reductions per transit passenger mile), which is recommended by the APTA to account for factors that enable transit at higher densities and around more varied mix of land uses that would otherwise occur by accounting for the indirect effects transit has on reducing vehicle travel associated with reduced trip lengths, facilitation of pedestrian and bicycling travel, trip chaining, and reduced vehicle ownership. The land use multiplier is applicable at the regional-level, rather than at the transit agency-level.

[39] American Public Transportation Association. APTA Standards Development Program Recommended Practice. *Quantifying Greenhouse Gas Emissions from Transit*. APTA SUDS-CC-RP-001-09. August 2009. Available at: https://www.apta.com/resources/standards/Documents/APTA%20SUDS%20CC-RP-001-09_Rev%201.pdf.

[40] Ibid.

b) Alternate Approach 1: Use region-specific survey data.
c) Alternate Approach 2: Use statewide 24-hour average value of 1.5.[41]

Step 6: Estimate average regional home-work (HW) trip lengths from travel demand model. It is assumed that transit and displaced private automobile trips are equal in length and one transit trip equals one displaced private automobile trip.[42]

Step 7: Calculate displaced VMT using the following equation. These are private automobile trips displaced (net reduction in VMT from strategy) by the transit feature implemented by the strategy and are associated with current regional fleet mix of private automobile trips for MPO region based on the current version of EMFAC.

$$VMT_{Dsp} = Ridership_{Base} \times Ridership_{Inc} \times MSF \times LU \times TL \div AVO$$

VMT_{Dsp} =	*Calculated displaced VMT (miles)*
$Ridership_{Base}$ =	*Baseline ridership (# of trips)*
$Ridership_{Inc}$ =	*Ridership increase (percentage)*
MSF =	*Mode shift factor (unitless)*
LU =	*Land use multiplier (unitless)*
TL =	*Average regional HW Trip Length (miles per trip)*
AVO =	*Average vehicle occupancy (unitless)*

Step 8: Obtain displaced private automobile trip CO_2 emission rates from the current version of EMFAC.[43]

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[41] California Department of Transportation. *California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C): Technical Supplement to User's Guide*. *Volume 4: Active Transportation, Park and Ride, Freight Projects, and Risk Analysis*. February 2017. Available at: http://www.dot.ca.gov/hq/tpp/offices/eab/docs/Cal-BCTechSupplementVol4v2.pdf.

[42] American Public Transportation Association. APTA Standards Development Program Recommended Practice. *Quantifying Greenhouse Gas Emissions from Transit*. APTA SUDS-CC-RP-001-09. August 2009. Available at: https://www.apta.com/resources/standards/Documents/APTA%20SUDS%20CC-RP-001-09_Rev%201.pdf.

[43] The Low Carbon Fuel Standards (LCFS) are not assumed to have a significant impact on CO_2 emissions from EMFAC's tailpipe emission estimates, since most of the emission benefits due to the LCFS come from the production cycle (upstream emissions) of the fuel rather than the combustion cycle (tailpipe). As a result, this analysis does not reflect any changes in CO_2 emissions associated with upstream activities (e.g., fuel refining, fuel transport, etc.) due changes in fuel type and consumption associated with mode shift from private automobiles to transit.

Step 9: Obtain increased transit trips and CO_2 emissions[44] (if applicable). These are emissions associated with any increases in transit directly attributed to the strategy being evaluated that would otherwise not occur if the strategy were not implemented.

Step 10: Estimate Total CO_2 emissions associated the strategy. This includes net decreases in CO_2 emissions from displaced private automobile trips and net increases in CO_2 emissions from increases in transit (if applicable).

$$CO_{2\ Net} = (VMT_{Dsp} * EMFAC_{Dsp}) - (Transit_{Inc} * Transit_{ER})$$

VMT_{Dsp} =	*Calculated displaced VMT (miles)*
$EMFAC_{Dsp}$ =	*EMFAC CO_2 emission rate (grams per mile)*
$Transit_{Inc}$ =	*Increase in transit activity (varies[45])*
$Transit_{ER}$ =	*Transit emission rate (varies[46])*

[44] Ibid.
[45] Increased transit activity evaluated could vary depending on the type of transit (e.g., bus, heavy rail, light rail, etc.) and associated emission source (VMT, kWh, BTU, etc.) being evaluated
[46] Ibid.

Challenges, Constraints, and Strategy Implementation Tracking

Challenges and Constraints

Transit routes and stops can often be located far apart from one another, as well as from rider start- and end-points, while transit stops can have limited parking. In addition, riders must frequently use two or more transit routes during a trip, greatly increasing the total time required to travel. Unfortunately, many transit stops are simply too far from a trip origin, a trip destination, or are not available on the day, or time of day, necessary for the trip. As a result, potential riders must often travel long distances or find alternative methods to access transit stops. Transit investments typically aim to serve commute trips, although commuting accounts for only 27% of total VMT.[47] Thus, increased transit investment for commute ridership could displace, at best, only a fraction of total VMT.

Emerging technologies, such as self-driving cars, TNC services (similar to an on-demand taxi), and drones have the capability of helping more people utilize transit, or to give people more reasons to avoid transit. Potential challenges and constraints that that should be considered include:

- Tracking/quantifying the effects single-occupancy VMT displaced by transit
- Identifying how increased transit service hours, increased transit lane miles, and increased transit boardings result in single-occupancy VMT displaced by transit
- Addressing the first mile/last mile issues
- Compensating for stagnant or decreasing transit ridership trends

Monitoring and Tracking

Potential methods to quantify a change in VMT after implementing a transit project include:

- Use survey data (e.g., local survey, California Household Travel Survey [CHTS], etc.) to compare how many people used transit before and after a strategy improvement was implemented
- Analyzing monitoring data specifically targeted at the transit project

MPOs can measure/track before and after strategy implementation:

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[47] California Department of Transportation Division of Research, Innovation and System Information. *Methodologies to Convert Other Modes of Travel to Vehicle Miles Traveled (VMT).* July2015. Available at: http://www.dot.ca.gov/newtech/researchreports/preliminary_investigations/docs/modes_to_miles_preliminary_investigation_7-6-15_final.pdf.

- Transit ridership/boardings
- Transit service hours

Obtaining survey data would allow a transit agency to determine how many people currently use transit (usually as a percentage of total trips) and what kind or trips are made with transit vehicles (e.g., “commute”, “school”, “recreation/exercise”, “shop/dine/errand”, and “work trip/meeting”). With successive survey data, various components can be determined, such as whether there is an overall increase or decrease in use of transit (either aggregate or per-capita) and where and why people use transit. However, surveys typically take multiple years to obtain useful data.

Bicycle and Pedestrian Facility Enhancement

Strategy Description

Bicycle and pedestrian facility enhancement strategies provide or improve active transportation access and connectivity in the region. The strategy aims to reduce GHG emissions by replacing short non-recreational vehicle trips, primarily commute trips, with bicycle or walking trips. This strategy includes both infrastructure projects (e.g., construction of new bike lanes or extension of existing bike lanes, complete streets, and parking infrastructure for bikes) and non-infrastructure projects (e.g., bike sharing programs, safe routes to schools). In addition, bicycle and pedestrian improvements can facilitate transit, connecting the first and last mile between transit station/ stops and origin/destination of trips.

Objectives

Bicycle and pedestrian facility enhancement strategy can potentially reduce GHG emissions by:

- Reducing short work-related motor vehicle trips and VMT
- Promoting alternative means of transportation
- Connecting the first and last mile of transit trips

Trip and Emissions Data Needs

In addition to the general input and assumption for off-model strategies, the following is a list of specific conditions and factors for bicycle and pedestrian facility enhancement strategies that MPOs should consider and document:

- Is there an existing or planned Bicycling and Pedestrian Master Plan?
- Length of average auto trip reduced (length of bike or walk trip)
- Adjustment factor to account for bike/pedestrian use for non-recreational trip purposes
- Activity center credit to account for regional connectivity

Quantification Methodology

Typically, GHG emission reductions from bicycle and pedestrian improvement strategies are a result of VMT reductions due to mode shift from vehicle trips to non-motorized trips. The following steps present a VMT reduction-based approach for estimating GHG emission reductions associated with bicycle and pedestrian facility improvement strategies. An MPO can also modify the quantification by analyzing the distribution of work trip length by sub-region and/or industry.

Step 1: Determine the percent increase in regional bicycling and pedestrian lane-miles resulting from the strategy compared to base year.[48]

Step 2: Determine the relationship between bicycling/pedestrian infrastructure (e.g., lane miles, bike lane/sidewalk presence, sidewalk width, etc.), increased bicycling/pedestrian commute trips, and decreased private automobile commute trips/VMT.

a) Preferred Approach: Use methods from regional and/or local bicycling and pedestrian master plan, region-specific study, or other empirical data sources.
b) Alternate Approach: Use most suitable elasticities[49] from **Table 16** or listed in tables found in CARB *Impacts of Pedestrian Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions* and *Impacts of Bicycling Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions* Policy Brief documents; or use most suitable elasticities

Table 16. Increases in Bicycle Commutes per Bike Path-Mile

Study	Population size[50]	Percent increase in bicycle commuting
Nelson and Allen (1997) [51]	20 big U.S. Cities with over 100,000 residents	0.069% per mile of bikeway per 100,000 residents
Dill and Carr (2003) [52]	35 big U.S. Cities with over 250,000 residents	1% per mile of Class II bike lane per square mile
Marshall and Garrick (2010)	24 medium-sized California Cities with populations of between 30,000 and 100,000	0.35% increase in bike commuting per 1% of bike lane increase 0.007% reduction in drive commuting per 1% of bike lane increase

[48] If the bicycle and pedestrian improvement strategy has a focus on local areas, the same methodology can be applied to determine the percent increase in bike/pedestrian lane-miles in the specific areas.
[49] Elasticity is the percent increase in bicycling/pedestrian commute trips for every 1% increase in bicycling/pedestrian lane miles.
[50] The three listed studies were all based on ACS census tract level data for big and mid-size MSAs, and are suitable for regional level analysis for MPOs.
[51] Nelson, A. C. & Allen, D. (1997). *If You Build Them, Commuters Will Use Them: Association Between Bicycle Facilities and Bicycle Commuting*. Transportation Research Record 1578, TRB, National Research Council, Washington, D.C., pp. 79–83.
[52] Dill, J & Carr, T. *Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them – Another Look*. Transportation Research Board 2003 Annual Meeting. Available at: http://www.des.ucdavis.edu/faculty/handy/ESP178/Dill_bike_facilities.pdf.

Step 3: Determine number of HBW purpose vehicle trips occurring within the region from travel model output.

Step 4: Estimate average regional HW trip lengths.

a) Preferred Approach: Use travel model output, regional and/or local bicycling and pedestrian master plan, region-specific study, or other empirical data sources.
b) Alternate Approach: Use average distance of 1.8 miles for biking and 0.98 mile for walking based on National Household Transportation Survey[53] data.

Step 5: Calculate mode shift VMT from private automobiles to bicycle and walking using the following equation.

$$VMT = Bike/ped\ lane\ mile_{\%\ Inc} * Bike/ped_{Inc} * \ Trips * TL$$

Bike/ped lane mile$_{\%\ Inc}$ =	*Increase in regional bike/pedestrian lane miles from strategy (percentage)*
Bike/ped$_{Inc}$=	*Increase in bicycling/pedestrian commute trips from increase in bicycling/pedestrian lane miles (varies[54])*
Trips =	*Regional HW Trips (# of trips)*
TL =	*Average regional HW Trip Length (miles per trip)*

Step 6: Obtain displaced private automobile trip CO_2 emission rates from the current version of EMFAC.[55]

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[53] U.S. Department of Transportation, Federal Highway Administration. *Summary of Travel Trends: 2009 National Household Travel Survey*. 2011. Available at: https://nhts.ornl.gov/2009/pub/stt.pdf.

[54] Relationship between bicycling/pedestrian lane miles and increased bicycling/pedestrian commute trips could vary, resulting in varying units depending on the relationship.

[55] The Low Carbon Fuel Standards (LCFS) are not assumed to have a significant impact on CO_2 emissions from EMFAC's tailpipe emission estimates, as most of the emission benefits due to the LCFS come from the production cycle (upstream emissions) of the fuel rather than the combustion cycle (tailpipe). As a result, this analysis does not reflect any changes in CO_2 emissions associated with upstream activities (e.g., fuel refining, fuel transport, etc.) due to changes in fuel type and consumption associated with mode shift from private automobiles to transit.

Step 7: Estimate CO_2 emissions associated the strategy.

$$CO_2 = VMT * EMFAC$$

VMT =	*Calculated displaced VMT (miles)*
EMFAC =	*EMFAC CO_2 emission rate (grams per mile)*

Challenges, Constraints, and Strategy Implementation Tracking

Challenges and Constraints

One of the biggest challenges in Bicycle and Pedestrian Facility Enhancements is how to effectively measure the effectiveness of such enhancements. Many monitoring technologies exist to measure bicycles and pedestrians on a sidewalk or bicycle lane. However, little monitoring data has apparently been completed, or if monitoring data has been collected, very little has been published in the literature. Without monitoring, the increase in bicycling or walking from a project cannot be quantified. Recently, Nordback and Sellinger[56] provided a method for using continuous automatic count data to calculate daily/hourly and monthly adjustment factors to apply to short-duration (e.g. peak-hour) bike counts to estimate annual average daily bicycle trips. CARB staff encourage MPOs to test the regional applicability of this method (or other methods from research.

Monitoring and Tracking

MPOs can track various metrics to ensure the SCS strategies are implemented and effective. MPOs may want to track:

- Policies (e.g., Complete Streets)
- Bike lane miles
- Specific bicycle and pedestrian facility projects

[56] Nordback, K., & Sellinger, M.). *Methods for Estimating Bicycling and Walking in Washington State.* WA-RD 828.1. May 2014. Available at: http://www.wsdot.wa.gov/research/reports/fullreports/828.1.pdf.

Bike Share

Strategy Description

Bike share programs allow members for a small fee to pick up a bike, ride to a destination, and leave it at a new location for another user to access. This strategy aims to reduce GHG emissions by providing access to bicycles and replacing auto trips with bike trips. Some bike share programs also include electric pedal-assist bikes to make it easier for members to go farther distances. Other similar strategies such as e-scooter sharing programs can follow the framework of quantification methodology in this section to estimate the potential GHG benefit.

Objectives

Bike share strategy can potentially reduce GHG emissions by:

- Reducing VMT by providing access to bicycles and replacing auto trips with bike trips

Trip and Emissions Data Needs

In addition to the general input and assumption for off-model strategies, the following is a list of specific conditions and factors for bike share strategy that MPOs should consider and document:

- Besides regular bikes for the program, does the MPO consider electric pedal-assist bikes, and other non-auto transportation equipment share program(s) (e.g., scooter share, skateboard share)?
- Average bike share/scooter share one-way travel distance

Quantification Methodology

The GHG emission reductions from bike share strategies are a result of VMT reductions due to mode shift from vehicle trips to non-motorized trips. The following steps present a VMT reduction-based approach for estimating GHG emission reductions associated with bike share/scooter share strategies. An MPO can also modify the quantification by analyzing the distribution of work trip length by sub-region and/or industry.

Step 1: Identify service areas[57] for each city with planned bike share program and determine the number of planned bike share stations and population for each service area.

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[57] A bike share service area is the geographical area a bike share user can park the bike when done riding, without incurring a fee for locking the bike outside of the service area; however, each bike share service provider can set their own rules regarding where users can park the bikes.

Step 2: Calculate the number of bike share stations per square kilometer (km) for each service area by dividing the number of planned bike share stations by the land area of each service area.

$$Bike\ share\ stations_{skm} = \sum \frac{Bike\ share\ stations}{Service\ area_{skm}}$$

Bike share stations$_{skm}$ =	*Bike share stations per square km per service area*
Bike share stations =	*Number of planned bike share stations per service area*
Service area$_{skm}$ =	*Area of each service area (square km)*

Step 3: Apply a regression formula derived from Institute for Transportation and Development Policy (ITDP) to estimate the number of daily bike share trips per 1,000 residents in each area:

$$Daily\ bike\ share\ trips\ per\ 1{,}000\ residents\ = 1.74 * station\ density + 17.2$$

Step 4: Estimate the number of daily bike share trips in each service area by multiplying the number of residents in each service area by the number of daily bike share trips calculated in Step 3.

$$Bike\ share\ trips_{SA} = \sum Residents_{SA} * \ Daily\ bike\ share\ trips$$

Bike share trips$_{SA}$ =	*Number of daily bike share trips per service area*
Residents$_{SA}$ =	*Number residents in each service area*
Daily bike share trips =	*Number of daily bike share trips per 1,000 residents*

Step 5: Multiply total daily bike share trips by the average population growth for the scenario year to estimate future total daily bike share trips.

Step 6: Estimate average regional HW trip lengths.

a) Preferred Approach: Use region-specific trip lengths from travel demand model, regional and/or local bicycling and pedestrian master plan, region-specific study, or other empirical data sources.

b) Alternate Approach: Use average distance of 1.8 miles for biking and 0.98 mile for walking based on National Household Transportation Survey[58] data.

Step 7: Estimate mode shift VMT reductions from private automobiles to bike share by multiplying the daily bike share trips calculated in Step 4 by the average regional HW trip lengths from Step 6.

$$VMT = Bike\ share\ trips_{SA} * TL$$

Bike share trips$_{SA}$ =	*Number of daily bike share trips per service area*
TL =	*Average regional HW Trip Length (miles per trip)*

Step 8: Obtain displaced private automobile trip CO_2 emission rates from the current version of EMFAC.[59]

Step 9: Calculate total CO_2 emission reductions by multiplying VMT reductions calculated in Step 7 by EMFAC exhaust emission rates from Step 8.

$$CO_2 = VMT * EMFAC * \ 12.4\%$$

VMT =	*Calculated displaced VMT (miles)*
12.4% =	*Bike Ride-displaced VMT for commutes or errands*[60]
EMFAC =	EMFAC CO_2 emission rate (grams per mile)

[58] U.S. Department of Transportation, Federal Highway Administration. *Summary of Travel Trends: 2009 National Household Travel Survey*. 2011. Available at: https://nhts.ornl.gov/2009/pub/stt.pdf.

[59] The Low Carbon Fuel Standards (LCFS) are not assumed to have a significant impact on CO_2 emissions from EMFAC's tailpipe emission estimates, as most of the emission benefits due to the LCFS come from the production cycle (upstream emissions) of the fuel rather than the combustion cycle (tailpipe). As a result, this analysis does not reflect any changes in CO_2 emissions associated with upstream activities (e.g., fuel refining, fuel transport, etc.) due changes in fuel type and consumption associated with mode shift from private automobiles to transit.

[60] Dill, J & Carr, T. *Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them – Another Look*. Transportation Research Board 2003 Annual Meeting. Available at: http://www.des.ucdavis.edu/faculty/handy/ESP178/Dill_bike_facilities.pdf.

Challenges, Constraints, and Strategy Implementation Tracking

Challenges and Constraints

A bike-friendly ecosystem is important to effectively implement this strategy. The ecosystem will require sufficient and connected bike-related Infrastructure, such as bike lanes, bike racks, and etc. However, these types of infrastructure are often beyond the scope of a bike-sharing program. Therefore, the effectiveness of bike sharing programs could be constrained by the readiness and availability of bike-related Infrastructure.

Bike commuters frequently use additional transportation modes for a trip, which can significantly increasing the total time required to travel. In addition, many bike share programs only provide service in a limited area (e.g., urban areas). As a result, potential bike commuters will need to plan for longer travel times and pay premium for using bikes and other modes, such as transit, which may increase total commute cost.

Many shared bikes are installed with route tracking devices (e.g., GPS) to help companies track use. However, it can be challenging to properly store and use this activity data. In addition, bike sharing program users may have privacy concerns. Currently, there are no specific regulations regarding bike share data storage. Improper usage of activity data, has a privacy risk, which may adversely affect someone’s willingness to participate in bike sharing programs.

Another potential challenge of bike sharing programs is the rider safety. Most bike sharing programs do not provide complimentary protective gear (e.g., helmet, knee pads, etc.), and only takes minimum responsibility if users get injured. These issues need to be addressed in the long-run to successfully implement bike sharing programs.

Monitoring/Tracking

- Specific bike share, e-scooter sharing or other related projects
- Number of bikes in bike sharing program
- Number of miles logged through bike sharing programs

Telecommuting/Work-At-Home

Strategy Description

Telecommuting/Work-At-Home (Telecommuting) is a TDM strategy that allows employees to work at home remotely by using a computer and/or telephone rather than commuting to a central workplace. The purpose of telecommute strategy is to reduce commuter motor vehicle work trips, with the telecommuters typically averaging 1.2 to 2.5 days telecommuting per week.[61] Telecommute generally does not include flexible or compressed work schedules,[62] but rather includes home-based businesses, contract workers working from home offices, and other more permanent work arrangements.

Objectives

Telecommute strategy can potentially reduce GHG emissions by:

- Reducing HBW vehicle trips and VMT
- Relief peak hour congestion in roadway network

Trip and Emissions Data Needs

In addition to the general input data and assumptions for off-model strategies listed in **Table 13** of the introduction section, the following is a list of specific conditions and factors MPOs should consider and document for telecommuting strategies:

- Average number of telecommute day(s) per worker or telecommuter for base and future analysis years.
- What are the occupational classifications[63] in the region that can participate in a telecommuting program?
- Are there potential populations for telecommuting for future RTP/SCS updates but currently not accounted for in the new RTP/SCS?
- What is the average travel distance for HBW trips in the region with and without telecommuting?[64]

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[61] Handy, S., Tal, G., & Boarnet, M. *Policy Brief on the Impacts of Telecommuting Based on a Review of the Empirical Literature*. December 2013. Available at: https://www.arb.ca.gov/cc/sb375/policies/telecommuting/telecommuting_brief120313.pdf.

[62] Different from telecommute strategy, flexible or compressed work schedules generally allow commuters to avoid peak-hour traffic and/or allow employee to have extra day off. The GHG benefit from flexible or compressed work is therefore different from telecommute strategy.

[63] U.S. Department of Labor, Bureau of Labor Statistics. Standard Occupational Classification. Available at: https://www.bls.gov/soc/.

[64] Data source can be from travel model output or observed data from the California Household Travel Survey (CHTS) or National Household Travel Survey (NHTS).

Quantification Methodology

If a telecommuting strategy is considered by an RTP/SCS to reduce GHG emissions, the MPO needs to clearly describe the assumptions, document the quantification of GHG emission reduction, provide the implementation plan associated with the telecommute strategy as proposed in the RTP/SCS (e.g., level of deployment, percent of workers use telecommute, occupations that are affected by this strategy), and how this strategy will continue into the future to further reduce commute trips related VMT and/or GHG emissions.

The MPO should also account for potential source(s) of the Rebound Effect applicable to the region as part of quantification. For example, commuters may be encouraged to live or move further away from workplaces in the long-term due to the promotion of telecommute or it may induce additional trips such as lunch or personal errands while an employee is working from home, which may range from 3.7 to 6 miles[65] (Reitan 2014; SCAG 2016). Data for the Rebound Effect may be obtained from regional data, studies, other empirical data sources, or the travel demand model.

The following steps present a VMT reduction-based approach for estimating the impact of a telecommuting strategy by considering the additional telecommuters will be affected, the additional work trips that will be reduced, the replaced VMT of a work trip and rebound effect. An MPO can also modify the quantification by analyzing the distribution of work trip length by sub-region and/or occupation.

Step 1: Identify the average home-based work (HBW) trip length in the region (or implemented area in the region)

a) Preferred Approach: Use HBW trip length data from the travel model
b) Alternate Approach: Use average HBW trip length from the observed household travel survey (e.g., CHTS or National Household Travel Survey [NHTS]).

Step 2: Identify the number of additional telecommuters resulting from the strategy based on regional data, studies, or other empirical data sources.

Step 3: Estimate the number of reduced HBW trips per commuter due to strategy

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[65] Reitan, F. *The Rebound Effect: A Simulation Model of Telecommuting*. June 2014. Available at: https://core.ac.uk/download/pdf/52107459.pdf. and Southern California Association of Governments. Final 2016 RTP/SCS Transportation System/Congestion Management Appendix. April 2016. Available at: http://scagrtpscs.net/Documents/2016/final/f2016RTPSCS_CongestionManagement.pdf.

Step 4: Identify and account for Rebound Effects using regional data, studies, other empirical data sources, or the travel demand model.

$$VMT\ reduction_{telecommute} = (Trip\ Length_{work\ trip} * Additional\ Telecommuters * Reduced\ work\ trips\ per\ commuter) - Rebound\ Effect\ (miles)$$

Challenges and Constraints

MPOs should summarize foreseeable challenges in the implementation of telecommuting strategies or more aggressive telecommuting strategies in the region. For example, workplace management concerns about supervising remote employees, security/privacy concerns, state tax laws (when crossing state boundaries) and their impact on corporate tax rate, individual taxes and sales tax application, applicability of potential Occupational Safety and Health Administration (OSHA) requirements and /or Americans With Disabilities Act (ADA) compliance, etc.

Other challenges and constraints could include rebound effects, as employees who work at home instead of commuting to typical office locations, potentially make local trips for lunch or run personal errands during break times. It can also be a challenge to identity the net effect on reducing commute trip VMT from other similar strategy (e.g., flexible schedule), which would require MPOs to refine categories of worker to indicate whether one is a telecommuter, or with a flexible work schedule.

Monitoring and Tracking

- Periodic commuter surveys to gather information on the annual participation rate of telecommute from employers,
- Average commute-related trip length,
- Discretionary vehicle trips associated with telecommuters on work-at-home days,

Car Sharing

Strategy Description

Car sharing is a membership-based strategy in which people rent cars for short periods of time, often by the hour where fees are typically priced on a per-mile or hourly basis. The environmental, social, land use, and transportation effects of car sharing programs are seen mainly in urban areas. Potential GHG-reducing benefits associated with car sharing include reduced vehicle ownership rates, single occupancy vehicle trips, and VMT, as trips shift to walking, biking, and public transit due to reduced driving associated with reduced auto ownership rates. In addition, vehicles used for car sharing are often newer and less polluting than older privately-owned vehicles whose trips are replaced by car sharing.

There are currently four different types of car sharing programs:[66]

1) **Traditional Roundtrip:** Members start/end trips at the same vehicle location and typically pay for use by the hour, mile, or both.
2) **One-Way:** Members pay by the minute and can start/end trips at different locations (either throughout a free-floating zone or station-based model with designated parking locations).
3) **Peer-to-Peer:** Similar to roundtrip except the vehicle fleet is typically owned/leased by private individuals and facilitated by a third-party operator.
4) **Fractional:** Users can co-own a vehicle and share costs and use.

By becoming car sharing members, households often shed one or all their vehicles. With reduced car ownership, other benefits are realized that reduce GHG emissions including alleviated parking and traffic congestion, and increased walking, biking and public transit use.

Objectives

The car sharing programs can potentially reduce GHG emissions by:

- Partially replacing private vehicles with shared vehicles
- Alleviating congestion by lowering the number of vehicles on the roads
- Lowering the overall VMT, ultimately cVMT (combustion VMT)
- Promote changes in fleet mix, such as reducing vehicle ownership and more zero emission vehicles (ZEV)

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[66]Lovejoy, K., Handy, S., & Boarnet, M. *Impacts of Carsharing on Passenger Vehicle Use and Greenhouse Gas Emissions*. October 2013. Available at: https://www.arb.ca.gov/cc/sb375/policies/carsharing/carsharing_brief.pdf.

- Diverse impacts on other modes

Trip and Emissions Data Needs

To quantify potential GHG emission reductions from car sharing strategies, MPOs should identify factors that promote and contribute to increasing car share membership, reducing VMT, and improving congestion. The following are categories of factors that CARB staff consider for the effectiveness of a proposed car sharing strategy and the appropriate quantification of GHG emission reductions.

- Number of vehicle trips reduced
- Average vehicle trip length
- VMT reduced

Quantification Methodology

The following lists the basic analytical steps that MPOs can consider when estimating GHG emission reductions associated with car sharing strategies. Key factors CARB staff considers essential in quantifying GHG emission reductions from car sharing strategies, include population, adoption rate, and VMT. Where available, region-specific data should be used. The overall approach is to quantify changes in VMT and their resultant effects to GHG emissions. MPOs can estimate residential densities for each individual Traffic Analysis Zone (TAZ) or similar geographic scales, as well as the population that is eligible and willing to adopt car sharing.

Step 1: Identify regions/County/City/TAZs that have sufficient residential densities to support car sharing. Research indicates the minimum residential density required for a neighborhood to support car sharing is five (5) residential units per acre.[67]

a) Preferred Approach: Use data from regional and/or local car share operators, region-specific study, or other local empirical data sources for local residential density support rate.
b) Alternate Approach: Use conservative local residential density support rate five (5) residential units per acre.

Step 2: Estimate Total Population of regions/County/City/TAZs identified in Step 1 as having sufficient residential densities to support car sharing.

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[67] Celsor, C. & Millard-Ball, A.I. *Where does Car-Sharing Work? Using GIS to Assess Market Potential*. 2007 Annual Meeting of the Transportation Research Board.

Step 3: Identify regional car share adoption rate.

Research from the Transportation Research Board's Transit Cooperative Research Program indicates that car share members are most likely to be between the ages of 25 to 45,[68] while 10% of individuals aged 21+ in metropolitan areas of North America would become members if it were more convenient.[69,70,71]

a) Preferred Approach: Use data from regional and/or local Car share operators, region-specific study, or other local empirical data sources for regional adoption rate.
b) Alternate Approach: Use conservative adoption rate of 10% of individuals aged 21 to 45. This number was derived from two car-sharing studies in major metropolitan/urban areas described above.

Step 4: Estimate car share membership population of region/County/City/TAZs identified as having sufficient residential densities to support car sharing (Step 2) using the car sharing adoption rate (Step 3).

$$Membership\ Population_{CS} = (Total\ Population_{CS} * \ Adoption\ Rate_{CS})$$

Membership Population$_{CS}$ =	*Number of car sharing members in region/County/City/TAZs*
Total Population$_{CS}$ =	*Total population of region/County/City/TAZs identified as having sufficient residential densities to support car sharing*
Adoption Rate$_{CS}$ =	*Car sharing adoption rate for region/TAZ*

Step 5: Estimate VMT reductions from vehicles discarded or shed by car sharing members.

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[68] Transportation Research Board, Transit Cooperative Research Program. *TCRP Report 108: Car-Sharing: Where and How It Succeeds*. 2005. Available at: https://www.cambridgema.gov/~/media/Files/CDD/Transportation/PTDM/PTDM_TCRP_108.ashx.

[69] Ibid.

[70] Shaheen, S., Cohen, A., & Robert, J. (2005). *Car Sharing in North America: Market Growth, Current Developments, and Future Potential.*

[71] *Hampshire, R., Achieving the Promise of the Sharing Economy: The Case of Peer-2-Peer Carsharing.* ND. Available at: http://sharingeconomy.umn.edu/events/symposium/2016/workshop/program/session2/documents/session2_hampshire.pdf.

Research by the University of California at Berkeley[72] indicates that car sharing leads to a net VMT reduction, which are associated with car sharing members sell their existing vehicles and reducing purchases of new vehicles. Research from the San José State University's Norman Y. Mineta International Institute for Surface Transportation Policy Studies (MTI) indicates that vehicles discarded or shed by car sharing members would otherwise have been driven 8,200 miles per year.[73] While VMT may slightly increase for specific car share members that did not previously own a car, the overall VMT tends to drop substantially for the car sharing membership fleet.

a) Preferred Approach: Use data from regional and/or local Car share operators, region-specific study, or other local empirical data sources to estimate the number of trips or miles per year that are associated with shed vehicles per car sharing member.
b) Alternate Approach: Use conservative estimate that shed VMT is 8,200 miles per year.[74]

$$Total\ VMT_{Shed} = (Membership\ Population_{CS} * VMT_{Memb\ Shed})$$

Total VMT_{Shed} =	*Total reduced VMT from shed vehicles in region/TAZs (miles/year)*
Membership $Population_{CS}$ =	*Number of car sharing members in region/TAZs*
$VMT_{Memb\ Shed}$ =	*reduced VMT shed per car share member per year (miles/member/year)*

Step 6: Obtain CO_2 emission rates for shed private automobiles from the current version of EMFAC.[75]

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[72] Martin, E. & Shaheen, S., (2016). *Impacts of Car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions: An Analysis of Five North American Cities*. Available at: http://innovativemobility.org/wp-content/uploads/2016/07/Impactsofcar2go_FiveCities_2016.pdf.

[73] Martin, E. & Shaheen, S. (2010). *Greenhouse Gas Emission Impacts of Carsharing in North America.* Available at: http://transweb.sjsu.edu/sites/default/files/Carsharing%20and%20Co2%20%286.23.2010%29.pdf.

[74] Ibid.

[75] The Low Carbon Fuel Standards (LCFS) are assumed to not have a significant impact on CO_2 emissions from EMFAC's tailpipe emission estimates, as most of the emission benefits due to the LCFS come from the production cycle (upstream emissions) of the fuel rather than the combustion cycle (tailpipe). As a result, this analysis does not reflect any changes in CO_2 emissions associated with upstream activities (e.g., fuel refining, fuel transport, etc.) due to changes in fuel type and consumption associated with mode shift from private automobiles to transit.

Step 7: Estimate CO_2 emission reductions from private automobiles shed by car sharing members.

$$CO_{2\,Shed} = Total\,VMT_{Shed} * EMFAC_{Shed}$$

$CO_{2\,Shed}$ =	*CO_2 emission reductions from shed vehicles in region/County/City/TAZs (grams/year)*
Total VMT_{Shed} =	*Total reduced VMT from shed vehicles in region/County/City/TAZs (miles/year)*
$EMFAC_{Shed}$ =	*Average EMFAC CO_2 emission rate for shed vehicles in region/County/City/TAZs (grams per mile)*

Step 8: Estimate VMT from car share members driving car share vehicles

CARB analysis of research conducted by MTI indicates that car share members drive on average 1,200 miles per year in a car share vehicle.[76]

a) Preferred Approach: Use data from regional and/or local TNC operators, region-specific study, or other local empirical data sources to estimate the average number of trips or miles per year driven per car sharing member.
b) Alternate Approach: Use conservative estimate that each car share member drives 1,200 miles per year in a car share vehicle.[77]

$$Total\,VMT_{CS} = (Membership\ Population_{CS} * \ VMT_{Memb\ CS})$$

Total VMT_{CS} =	*Total VMT from car share members driving car share vehicles in region/TAZs (miles/member/year)*
Membership $Population_{CS}$ =	*Number of car sharing members in region/TAZs*
$VMT_{Memb\ CS}$ =	*Car share VMT per member per year in region/TAZs (miles/member/year)*

Car share vehicles are expected to be more fuel efficient than the average fleet. Vehicles used for car sharing are often newer and less polluting than older privately-owned vehicles whose trips are replaced by car sharing. California's car sharing services offer a variety of vehicles to members however, compared

[76] CARB calculated Martin, E. & Shaheen, S. (2010). *Greenhouse Gas Emission Impacts of Carsharing in North America.* Available at: http://transweb.sjsu.edu/sites/default/files/Carsharing%20and%20Co2%20%286.23.2010%29.pdf.
[77] Ibid.

to the average light duty fleet, the vast majority of the car sharing fleet are low and zero emission vehicles (ZEV) such as hybrids, PHEVs or a Battery Electric Vehicles (BEV). Until the average light duty fleet in CA will reach the same ratio of conventional/combustion vs. low/zero emission vehicles (cVMT vs eVMT), the car sharing fleet is on average more fuel-efficient. This difference in fuel usage represents, when converted, a direct GHG emission reduction. CARB analysis of research conducted by MTI indicates that car sharing vehicle fleets are typically 29% more efficient than the overall population of vehicles shed by car sharing members.[78]

a) Preferred Approach: Use average local car sharing mix fleet based on data from regional and/or local TNC operators, region-specific study, or other local empirical data sources to identify average fleet-specific mix and age distribution to estimate car share fleet emission rates from the current version of EMFAC.[79]
b) Alternate Approach: Obtain CO_2 emission rates for shed private automobiles from the current version of EMFAC[80] and reduce by 29%.

Step 10: Estimate CO_2 emissions from car sharing vehicle operation.

$$CO_{2\,CS} = Total\,VMT_{CS} * EMFAC_{CS}$$

$CO_{2\,CS}$ =	*CO_2 emissions from car share vehicles in region/TAZs (grams)*
Total VMT_{CS} =	*VMT from car share vehicles in region/TAZs (miles)*
$EMFAC_{CS}$ =	*EMFAC CO_2 emission rate for car share vehicles in region/TAZs (grams per mile)*

Step 11: Estimate total CO_2 emissions associated with car sharing in the region/TAZs.

$$Total\,CO_{2\,CS} = CO_{2\,shed} + CO_{2\,CS}$$

[78] Ibid.
[79] The Low Carbon Fuel Standards (LCFS) are assumed to not have a significant impact on CO_2 emissions from EMFAC's tailpipe emission estimates, as most of the emission benefits due to the LCFS come from the production cycle (upstream emissions) of the fuel rather than the combustion cycle (tailpipe). As a result, this analysis does not reflect any changes in CO_2 emissions associated with upstream activities (e.g., fuel refining, fuel transport, etc.) due to changes in fuel type and consumption associated with mode shift from private automobiles to transit.
[80] Ibid.

Total $CO_{2\ CS}$ =	*Total CO_2 emissions from car share strategy (grams/year)*
$CO_{2\ Shed}$ =	*CO_2 emission reductions from shed vehicles in region/County/City/TAZs (grams/year)*
$CO_{2\ CS}$ =	*CO_2 emissions from car share vehicles in region/County/City/TAZs (grams/year)*

Challenges, Constraints, and Strategy Implementation Tracking

Challenges and Constraints

- Is there sufficient local empirical data sets available to identify:
    - Residential densities that support car sharing
    - Car share adoption rate
    - VMT reductions from shed vehicles
    - VMT associated with car share vehicles driven by car share members
    - Shed vehicles and car share fleet characteristics
- Does the region have sufficient residential density to support car sharing?
- Do the types of car sharing programs (i.e., traditional roundtrip, one-way, peer-to-peer, and fractional) have different adoption rates?

Monitoring and Tracking

- Regions/TAZs that support car sharing
- Car share member statistics before and after strategy implementation
- VMT reductions from shed vehicles or trips
- VMT associated with car share vehicles driven by car share members

Electric Vehicle Charging Infrastructure

Strategy Description

The goal of the electric vehicle (EV) Charging Infrastructure strategy is to increase the number of workplace EV chargers in a region to facilitate workplace plug-in hybrid vehicles (PHEVs) [81] charging by employees where the infrastructure is installed at workplaces. Currently, the average all-electric range (AER) of the PHEV fleet in California is approximately 33 miles per day per vehicle (mi/d/veh), while the average in-situ PHEV electric-drive range for this fleet is usage is only 20 eVMT per day per vehicle (/d/veh).[82] This difference between AER and average PHEV electric-drive range indicates PHEV drivers are choosing to operate their PHEVs in gasoline operating mode rather than electric operating mode.

Currently, the average all-electric range (AER) of the PHEV fleet in California is approximately 33 eVMT/d/veh, while the electric usage is only 20 eVMT/d/veh.[83] This difference between AER and average PHEV electricity usage indicates PHEV drivers are choosing to operate their PHEVs in gasoline operating mode rather than electric operating mode. Shifting the PHEV's VMT from gasoline to electric would reduce tailpipe CO_2 emissions.

The strategy assumes PHEV batteries are fully charged prior to an employee beginning a commute trip to their workplace from home. Charging at home allows the owner to use low-cost night-time electricity which makes the electricity cheaper than gasoline. Since the PHEV's regular electricity usage is about 20 e-mi/d, with an average daily driving range of 33 mi/d, the average PHEV would have to charge at a non-home charger to avoid switching to gasoline operation. It would be naturally convenient for the PHEV to "top off" its battery during work hours through the workplace charging infrastructure. To further incentivize the PHEV driver to use electricity, it is suggested that the employer provide free electricity.

As part of this strategy, the following financial incentives would be provided:

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[81] PHEVs, in general, have an option to operate in gasoline or electric mode, unlike BEVs. As such, the goal of the strategy is to facilitate PHEV workplace charging and is not intended to capture BEVs

[82] CARB. 2017 Unpublished.

[83] California Air Resources Board 2017. Unpublished data and California Air Resources Board. *California's Advanced Clean Cars Midterm Review: Summary Report for the Technical Analysis of Light Duty Vehicle Standards*. Appendix G. Table 14. January 2017. Available at: https://www.arb.ca.gov/msprog/acc/mtr/acc_mtr_finalreport_full.pdf.

1. A one-time financial subsidy for the purchase and installation of workplace EV chargers for PHEVs.
2. When gasoline is cheaper than electricity on a per-mile basis, on-going incentives offered to employers to subsidize[84] PHEV-driving employees to charge their cars to help incentivize the operation of PHEVs in electric operating mode over gasoline operating mode.

In addition, to facilitate use of workplace EV chargers by employees, providing subsidized power to employees through the employer (subsidized power would help to make electric charging cheaper than gasoline to disincentivize gasoline operation) would facilitate implementation of this off-model strategy would allow PHEV drivers to charge at home and recharge at work to increase electrical usage.

Objectives

Electric Vehicle Charging Infrastructure strategies can reduce GHG emissions as follows:

- Increasing PHEV eVMT
- Decreasing PHEV cVMT

Trip and Emissions Data Needs

In addition to the general input data and assumptions for off-model strategies listed in **Table 13** of the introduction section, the following is a list of specific conditions and factors MPOs should consider and document for electric vehicle charging infrastructure strategies:

- The number of new workplace EV charging stations
- How many vehicles may be charged per EV charging station?
- How many PHEVs are in the region?
- The number of PHEVs participating in the program
- How many EV charging facilities will be implemented as part of the program?

[84] Subsidies would be required because economic conditions (e.g., fluctuations in gasoline and electricity prices) may preclude drivers from fully charging a PHEV at work and running in full electric operating mode. Such conditions may occur if the cost per mile for gasoline is cheaper than for electricity. Because workplace charging during a “typical” daytime workday would overlap with the period of the day when utility electricity rates are traditionally highest (most utilities offer rates that are least expensive during nighttime “off-peak” hours), workers may have no financial incentive to utilize workplace EV chargers. Consequently, subsidies would offset the increased cost of EV charging and make it more financially attractive than gasoline fueling, leading to increased electric-mode operation and decreased gasoline-mode operation.

- What is the electric range of PHEVs in the region?
- What is the driving length frequency distribution of drivers (i.e., how far does the average PHEV drive each day above its all-electric range)?

Quantification Methodology

The following presents the basic analytical steps that MPOs can consider when estimating emissions associated with the installation of workplace/public EV chargers. The overall approach is to determine the increased electric vehicle mileage traveled (eVMT) due to workplace and public charging at EV charging stations installed by the strategy.

The estimate of GHG emission reductions from increased EV charging infrastructure due to the strategy can be based upon two different initial approaches based on how the strategy is set up:

a) Estimate CO_2 emission reductions from PHEV eVMT based on estimated average VMT shift per PHEV from gasoline to electricity (cVMT to eVMT) as a result of increased workplace and public charges
b) Estimate CO_2 emission reductions from reduced gasoline consumption based on estimated electricity consumption increase as a result of increased workplace and public charges

Both of these approaches are described in detail below

Method a): Estimate CO_2 emission reductions from PHEV eVMT based on estimated average VMT shift per PHEV from gasoline to electricity (cVMT to eVMT) as a result of increased workplace and public charges

Part 1: Estimate EV population associated with strategy

Step 1: Identify number of workplace EV chargers ($Charger_{Region}$) to install in the region as part of strategy based on funding commitment and/or policies.

Step 2: Estimate the average number of PHEVs per charger installed ($PHEV_{Charger}$).

a) Preferred Approach: Use regional data, studies, or other empirical data sources.

b) Alternate Approach: Assume seven (7) PHEVs per charger based on National Renewable Energy Laboratory (NREL) data[85].

Step 3: Identify the number of PHEVs in the region that could use EV chargers installed as a result of the strategy ($PHEV_{Region}$) based on $Charger_{Region}$ from Step 1 and $PHEV_{Charger}$ from Step 2.

$$PHEV_{Region} = Charger_{Region} * \; PHEV_{Charger}$$

$PHEV_{Region}$ =	*Regional PHEV population affected by strategy*
$Charger_{Region}$ =	*Number of regional EV chargers installed in the region as part of the strategy (Step 1)*
$PHEV_{Charger}$ =	*Average number of PHEVs per charger (Step 2)*

Part 2: Estimate eVMT associated with the strategy

Step 4: Estimate the average increase in eVMT per PHEV ($PHEV_{eVMT}$) for the region as PHEV operating mode is shifted from gasoline to electric through increased workplace EV charging as a result of strategy implementation.

a) Preferred Approach. Perform or compile results of instrumented vehicle studies which document PHEV trip length, driving frequency and electric range, as well as local sales or registrations of PHEVs and data from https://www.fueleconomy.gov/ for each PHEV model, to determine the regional average trip length per PHEV to first electrical fill-up.

b) Alternative approach 1. Use data from other regional data, studies, or empirical data sources.

c) Alternative approach 2. Assume an average of 13 eVMT increased per day per PHEV using a workplace EV charging connector.[86]

Step 5: Estimate the total increased PHEV eVMT in the region ($eVMT_{Region}$) resulting from strategy implementation based on the number of PHEVs in

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[85] Melaina Marc, Michael Helwig. 2014. California Statewide Plug-In Electric Vehicle Infrastructure Assessment. Page 21. Figure 8. Final Report of National Renewable Energy Laboratory to California Energy Commission under Agreement 600-11-002. California Energy Commission, Sacramento, CA. Publication Number: CEC-600-2014-003. Available at: https://www.nrel.gov/docs/fy15osti/60729.pdf

[86] CARB. 2017 Unpublished. Internal CARB analysis of Southern California vehicle trip data indicating that workplace EV charging connectors would increase average PHEV e-miles by 13 e-miles per day per PHEV from 20 e-miles per day per PHEV to the 2016 State-average all-electric range for PHEVs of 33 miles per day.

the region affected by the strategy (Step 3) and the average increase in eVMT per PHEV for the region (Step 4)

$$eVMT_{Region} = PHEV_{Region} * \ PHEV_{eVMT}$$

$eVMT_{Region}$ =	*Total increased PHEV eVMT for the region*
$PHEV_{Region}$ =	*Regional PHEV population affected by strategy (Step 3)*
$PHEV_{eVMT}$ =	*Average increase in eVMT per PHEV for the region (Step 4)*

Part 3: Estimate CO_2 emissions associated with the strategy

Step 6: Obtain average emission factor for decreased PHEV gasoline consumption (Emission $Factor_{Gas}$) as PHEV operating mode is shifted from gasoline to 100% electric through increased workplace EV charging as a result of strategy implementation. Assume 198 grams of CO_2 is avoided for each PHEV mile transferred from gasoline to electric operation.

Step 7: Determine total regional GHG emission reductions due to the shift in PHEV operating mode from gasoline to electric ($CO_{2\ PHEV}$) using the total increased PHEV eVMT for the region (Step 5) and decreased PHEV gasoline consumption emission factor (Step 6).

$$CO_{2\ PHEV} = eVMT_{Region} * \ Emission\ Factor_{Gas}$$

$CO_{2\ PHEV}$ =	*Total regional CO_2 emission reductions from shift in PHEV operating mode from gasoline to electric*
$eVMT_{Region}$ =	*Total increased PHEV eVMT for the region (Step 5)*
Emission $Factor_{Gas}$ =	*Emission factor from avoided PHEV gasoline consumption (Step 6)*

Method b): Estimate the GHG reductions based on electricity consumptions of EV Chargers associated with the Strategy

Step 1: Estimate the CO_2 reductions per unit amount of electricity consumption (i.e., convert cVMT to eVMT) in the region.

$$CO_{2\,Credit} = Emission\ Factor_{Electricity} * Electricity_{Consump}$$

$CO_{2\,Credit}$ =	*CO_2 reductions per kW*hr charged at EV Charger (grams CO_2/kW*hr)*
Emission $Factor_{Gas}$ =	*PHEV emission factor (grams CO_2/mile). Default is 240 grams/mile[87].*
$Electricity_{eVMT}$ =	*Electric power used per eVMT (kW*hr/mile). Default is 0.36 kW*hr/mile[88].*

The default CO_2 credit is 666.66 g/kWhr (i.e.,240 grams/mile ÷ 0.36 kWhr/mile = 666.66 grams/kWhr).

MPOs may use region data for EV population, region-specific study, or other local empirical data sources to estimate the regional-specific unit CO_2 credit rates.

Step 2: Estimate the electricity consumption per charger by changer type

$$Electricity\ consumption_i = H_i * P_i * \eta_i$$

Electricity $consumption_i$ =	*Electricity consumption by charger type (e.g.,Level 2 or DC Fast Charger)*
H_i =	*Active hours charged by charger type,per charger,per day (hours/charger)*
P_i =	*Power rating of charger type. (see **Table 17**)*
η_i =	*Charger efficiency (MPOs may need to provide supporting document for this parameter)*

Table 17 is an example of power rating by charger type provided by NREL. MPOs may use regional data sources with more accurate estimates.

Table 17. Power Rating by Charger Type

	Home	Workplace	Public	Fast Charger
Power	1.1 to 3.3 kW	7.7 kW	7.7 kW	50+kW

[87] CARB. 2017 Unpublished. Internal CARB analysis of manufacturer sales data in California indicates the State-average CO_2 emissions for PHEV operation on gasoline as of 2016 is 240 grams/mile, PHEV tailpipe emissions on electricity are taken to be 0 g/mi, and electric power consumption is 360W*hr/mile.

[88] Ibid.

Step 3: Identify the number of workplace EV chargers by charging type ($Charger_i$) installed in the region as part of strategy.

Step 4: Estimate the average number of EVs per charger installed by charger type ($EV_{charger\_i}$).

a) Preferred Approach: Use regional data, studies, or other empirical data sources. **Table 18** gives an estimate of the theoretical maximum value of EV capacity per public or workplace chargers.

Table 18. Charge Connection to PHEV Ratio

Charger Type	Home	Workplace	Public	Fast Charger
EVI PRO[89]		1:61	1:107	1:1,048
NREL[90]	1:1	1:12	1:51	1:2,100

b) Alternate Approach: Assume average seven (7) PHEVs per charger based on National Renewable Energy Laboratory (NREL) data[91].

Step 5: Determine the total regional electricity consumption from EVs associated with the installation of EV charging infrastructure using the data from Steps 2 through 4.

$$Electricity\ consumption\ = \sum Electricity\ consumption_i * \ Charger_i * EV\ Charger_i$$

Electricity consumption =	*Total regional electricity consumption (kW-hr)*
Electricity consumption$_i$ =	*Daily electricity consumption from one charger of type, i (Step 2)*
Charger$_i$ =	*Number of workplace EV chargers (by type) in the region attributable to the strategy (Step 3)*
EV Charger$_i$ =	*Average number of EVs per charger by charger (Step 4)*

Step 6: Determine the total regional GHG emission reductions due to the installation of EV charging infrastructures using the CO_2 credit per unit electricity (Step 1), and the total electricity consumption (Step 5).

89 U.S. Department of Energy. Energy Efficiency & Renewable Energy Alternative Fuels Data Center. ND. Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite: How Much Electric Vehicle Charging Do I Need in My Area? Available at: https://afdc.energy.gov/evi-pro-lite.

90 Melaina Marc, Michael Helwig. 2014. California Statewide Plug-In Electric Vehicle Infrastructure Assessment. Page 21. Figure 8. Final Report of National Renewable Energy Laboratory to California Energy Commission under Agreement 600-11-002. California Energy Commission, Sacramento, CA. Publication Number: CEC-600-2014-003. Available at: https://www.nrel.gov/docs/fy15osti/60729.pdf.

91 Ibid.

$$CO_{2\,region} = CO_2\ credit * \ Electricity\ consumption$$

$CO_{2\ Region}$ =	*Total regional CO_2 emission reductions due to installation of EV charging infrastructure*
$CO_{2\ Credit}$ =	*CO_2 emission credit per unit amount of electricity consumption (grams CO_2/kW*hour) (Step 1)*
Electricity consumption =	*Total regional electricity consumption (kW-hr) (Step 5)*

Challenges, Constraints, and Strategy Implementation Tracking

Challenges and Constraints

- The goal of the strategy is to increase PHEV eVMT per day and not to increase purchases of PHEVs. Increased PHEV purchasing is addressed by other strategies.
- Both of the proposed methods can only provide accurate estimates for GHG reductions if individual chargers' actual active hours and electricity usage can be provided accurately.
- PHEV electric range would not increase as a result of the strategy. Rather, the strategy will allow workplace charging to facilitate the operation of the PHEV in electric mode and limit operation in gasoline mode.
- The choice of electricity over gasoline in a PHEV depends upon the relative price (cost/mile) of vehicle repowering. It is critical to the success of this strategy to have a low competitive price for electricity, whether from the power company rate structure or from direct employer subsidy.
- To maximize PHEV usage at workplace chargers, it is suggested to allow them to charge for free.

Monitoring/Tracking

- The number of workplace EV charging connectors installed by the strategy
- The number of PHEVs in the region utilizing workplace EV charging connectors installed by the strategy
- The amount of electricity consumed by EV charging facilities implemented from the strategy

Parking Management

Strategy Description

Parking management strategies aim to reduce GHG emissions by reducing vehicle trips and promoting alternative modes of transportation through methods such as pricing mechanisms, allowable hours of parking, or parking permits. These strategies can potentially improve and increase turnover rates for parking availability in impacted areas, and reduce parking search time and the associated VMT and GHG emissions. Several existing parking management strategies include the following:[92]

- Long/short-term fee differentials
- On-street fees and resident parking permits
- Workplace parking pricing
- Reduced reliance on minimum parking standards
- Adaptive parking pricing

For example, parking management can be a strategy for reducing work and discretionary trips from new development in a region through lowering the standards for minimum parking availability. Parking management can also be strategy for discouraging vehicle trips through installing parking meters and assigning limited hours for parking areas that are currently offered for free.

Objectives

Parking management strategies can reduce GHG emissions as follows:

- Reduced vehicle trips
- Reduced VMT
- Reduced vehicle circulation time for parking)
- Shift of other modes of travel

Trip and Emissions Data Needs

In addition to the general input data and assumptions for off-model strategies listed in **Table 13** of the introduction section, the following is a list of specific conditions and factors MPOs should consider and document for parking management strategies:

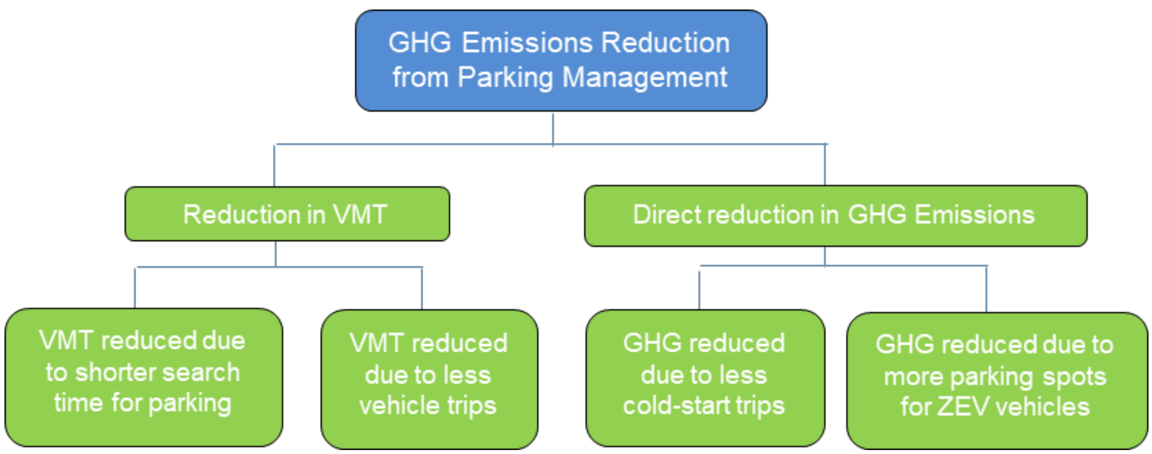
- Number of vehicle trips reduced
- Average vehicle trip length in the implemented area
- Parking generation rate associated with different land use for new development
- Parking turnover rates before and after the implementation of strategy
- Reduced circling time for parking search

[92] Handy, S., Boarnet, M., et al., *Senate Bill 375 - Research on Impacts of Transportation and Land Use-Related Policies.* October 2014. Available at: https://arb.ca.gov/cc/sb375/policies/policies.htm.

Quantification Methodology

Figure 1 illustrates the general path for quantification of GHG emission reductions from parking management related strategies. All GHG emission reductions are generally attributable to reductions in VMT (due to shorter search times for parking and less vehicle trips) and/or direct GHG emissions (due to less cold-start trips and more parking spots for ZEV vehicles). MPOs can develop their own methods to quantifying GHG benefits for parking management related strategies, which needs to reflect the pathway, key assumptions and factors that CARB staff consider in the evaluation process.

Figure 1. Quantify GHG Emission Reductions from Parking Management



The following are the basic analytical steps that MPOs can consider when estimating VMT and/or GHG emission reductions associated with parking management strategies. An MPO may prefer to develop their own methodology, but should reflect the components identified in CARB's approach.

Step 1: Quantifying VMT reduced due to shorter searching time for parking:

$$VMT_{Parking} = v_{Avg} * t_{Saved}$$

$VMT_{Parking}$ =	*VMT reduced due to shorter search time for parking (mile)*
v_{Avg} =	*verage travel speed on local street (mph)*

t_{Saved} = *Time saved from parking (hour)*

Step 2: Quantifying VMT reduced due to less vehicle trips. Assume on average 4 work days and 52 weeks per year.

$$VMT_{vt\_work} = 52\ weeks * \frac{4\ days}{week} * 2d_{HBW} * N_{sov}$$

VMT_{vt_work} = *VMT reduced due to reduction of work trips (mile)*

d_{HBW} = *Average trip length of HBW trips (mile/day)*

N_{SOV} = *Number of SOV commuters who shift to alternative modes*

$$= 52\ weeks * \frac{4\ days}{week} * 2d_{other} * N_{other}$$

VMT_{vt_other} = *VMT reduced due to reduction of non-work related trips (mile)*

d_{other} = *Average trip length of non-work trips (mile/day)*

N_{other} = *Number of non-work trips that switch from SOV mode to alternative modes*

Step 3: GHG emission reductions from less cold-start vehicle trips due to more frequent turnover rate

$$GHG_{cold-start/vehicle} = EF_{CO2\_cold\_start} * t_{warm-up}$$

$GHG_{cold\text{-}start/vehicle}$ = *Net GHG emission reduction for one less cold-start vehicle*

$EF_{CO2\ cold\text{-}start}$ = *CO_2 cold-start emission (grams/second)*

$T_{warm\text{-}up}$ = *Average time for light-duty vehicles warm up (seconds)*

Step 4: GHG emission reductions from ZEV vehicle trips that replace ICE vehicle trips due to the increase of dedicated parking spots for ZEV vehicles

$$GHG_{ZEV} = EF_{CO2\_ICE} * TR_{ZEV}$$

GHG_{ZEV} = *ZEV vehicle GHG reductions*

EF_{CO2_ICF} =	*Average CO_2 emission rate of the ICE vehicles replaced by ZEV*
TR_{ZEV} =	*Trip rates of ZEV that replace ICE vehicles in the implemented area*

Challenges, Constraints, and Strategy Implementation Tracking

Challenges and Constraints

A main challenge to parking management policy planning is that MPOs and/or local jurisdictions need to partner with communities to identify the rates and hours of parking that would be effective in reducing GHG emissions. Especially in developing areas, proposal parking management policy needs to consider the unforeseen demand as well. Another possible challenge would be to isolate parking management strategy's impact on reducing VMT and/or GHG emissions from other strategies that potentially have a similar impact on the affected population and implemented areas. For example, high cost of parking can promote travelers to consider transit as an alternative means of transportation. However, a direct transit strategy (e.g., more frequent transit service) can also motivate travelers in the same planning area to switch from an auto mode to a transit mode.

Monitoring and Tracking

For progress and effectiveness monitoring of each specific parking management strategy, MPOs can consider measuring the trip rates of before and after the implementation of new parking policies, or other means that can indicate performance of the policies. **Table 19** lists examples of potential monitoring steps and tracking system that MPOs can considering regarding parking management strategies.

Table 19. Potential Effort in Monitoring/Tracking Implementation of Parking Management Policy

Example of Specific Strategy	Ideas for Monitoring/Tracking
Reduce work and discretionary vehicle trips from new development areas	• Compare the planned/issued number of parking spaces in the new development areas to that of conventional standards • Conduct traffic counts in the new development areas to track vehicle trips, and compare the data to those of similar developments without this specific parking management policy
Enforce restrictions on hours and cost on street parking	• Records of meters install or blocks of street/spaces converted from free parking to enforced parking with limits on hours • Change of turnover rates of parking in enforced area(s) before and after policy

Electric Vehicle Incentive

Strategy Description

Zero Emission Vehicles (ZEV) are typically more expensive than new non-ZEV's, which can result in consumers having an indirect and unintended financial incentive to purchase non-ZEVs. The overall goal of the Electric Vehicle Incentive strategy is to help facilitate the purchase of new ZEV's in lieu of new non-ZEV by offering incentives in the form of rebates or subsidies that would partially offset the cost differential between these vehicles to consumers that might otherwise purchase a new non-ZEV.

MPOs would establish an incentive program where rebates or subsidies are provided to consumers for the purchase of a new ZEV.[93] The Electric Vehicle Incentive program would be separate from CARB's Clean Vehicle Rebate Project (CVRP), which is designed to promote the purchase of battery electric, plug-in hybrid electric, and fuel cell electric vehicles through rebates for the purchase or lease eligible vehicles. As of March 2019, the CVRP has over $75 million in funds remaining.[94]

In the event consumers were to receive rebates or subsidies through the Electric Vehicle Incentive created by the MPO and another existing incentive program, such as the CVRP, GHG emission reduction would be allocated to the respective incentive

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[93] It is recommended that the Electric Vehicle Incentive program only apply to new car purchases due to numerous variables and factors that may make application of the program to used cars infeasible and/or impracticable (e.g., used cars have a wider degree of CO_2 emission factors than new cars).
[94] California Clean Vehicle Rebate Project. *CVRP Funding Status*. Available at: https://cleanvehiclerebate.org/eng/rebate-funding-status.

programs based on the portion of the total funding each incentive program provides to the consumer.

Objectives

Electric Vehicle Incentive strategies reduce GHG emissions by maximizing electric driving through increasing new ZEV purchases.

Trip and Emissions Data Needs

In addition to the general input data and assumptions for off-model strategies listed in **Table 13** of the introduction section, the following is a list of specific conditions and factors that MPOs should consider and document for Electric Vehicle Incentive strategies:

- In addition to CARB's CVRP, are there existing Electric Vehicle Incentive programs already in use or currently planned that consumers may obtain funding from?
- Total amount of funding allocated for the subsidy/rebate program
- Subsidy/rebate amount for individual ZEV
- Number of new ZEV purchases

Quantification Methodology

The following lists the basic analytical steps that MPOs can consider when estimating GHG emission reductions associated with Electric Vehicle Incentive strategies. The overall approach to quantifying GHG emission reductions from the Electric Vehicle Incentive strategy is to first establish the total funding allocated to the subsidy/rebate program established by the MPO, as well as the amount(s) offered for individual subsidies/rebates. Once these two values have been set, the total number of new ZEV's that may be purchased under the incentive program can then be estimated. Based on the number of vehicles purchased under the incentive program and average trip lengths for the region, total VMT associated with the incentive program can be calculated. GHG emission reductions associated with the incentive program can then be estimated using the calculated VMT and emission factors derived from the most recent version of EMFAC.[95]

Step 1: Identify the total funding (*Total Program Funds*) allocated for the subsidy/rebate program established by the MPO

[95] California Air Resources Board. *Mobile Source Emissions Inventory*. March 2018. Available at: https://www.arb.ca.gov/msei/msei.htm.

Step 2: Identify the individual ZEV subsidy/rebate amount (*Subsidy/Rebate Amount*) for the subsidy/rebate program established by the MPO

Step 3: Estimate the number of new ZEV's (*Total Program ZEV*) that could be purchased through the subsidy/rebate program established by the MPO $[\frac{Step\ 1}{Step\ 2}]$

$$Total\ Program\ ZEV = \frac{Total\ Program\ Funds\ [Step\ 1]}{Subsidy/Rebate\ Amount\ [Step\ 2]}$$

Total Program ZEV =	*Number of ZEV's purchased through the subsidy/rebate program*
Total Program Funds =	*Total funding allocated to subsidy/rebate program [Step 1]*
Subsidy/Rebate Amount =	*Individual subsidy/rebate amount [Step 2]*

Step 4: Identify the average trip length (*Average Trip Length*). Use the daily usage for a vehicle (miles per day per vehicle) from EMFAC.

Step 5: Calculate the average total eVMT from all trip purposes (*ZEV VMT*) associated with new ZEV's purchased through the incentive program $[Step\ 3 * Step\ 4]$

$$ZEV\ VMT = Total\ Program\ ZEV\ * Average\ Trip\ Length$$

ZEV eVMT =	*Average eVMT from ZEV's purchased through the subsidy/rebate program*
Total Program ZEV's =	*Number of new ZEV's purchased through the subsidy/rebate program [Step 3]*
Average Trip Length =	*Regional average trip length [Step 4]*

Step 6: Obtain the average regional GHG emission factors for new non-ZEV's (*Non-ZEV EF*) replaced by new ZEV's purchased through the incentive program from the most recent version of EMFAC[96].

[96] California Air Resources Board. *Mobile Source Emissions Inventory, EMFAC2017*. Available at: https://www.arb.ca.gov/msei/msei.htm.

Step 7: In addition to MPOs incentive program, if other rebate or incentive programs are utilized for the Electric Vehicle Incentive strategy (e.g., CVRP), calculate the MPO's fraction of overall EV incentives provided.[97]

$$MPO\ Electric\ Vehicle\ Incentive\ Strategy\ Fraction = \frac{MPO\ Electric\ Vehicle\ Incentive\ amount}{Total\ \ incentive\ amount}$$

MPO Electric Vehicle = Incentive Strategy Fraction	*Amount of GHG reductions MPOs may claim from the strategy if multiple rebate/incentive programs are utilized*
MPO Incentive amount =	*Subsidy rebate rate from Step 2*
Total incentive amount =	*Total incentive amount received by individual vehicles, including MPO subsidy/rebates and subsidy, rebates, and vouchers from other sources.*[98]

Step 8: Calculate *GHG emission reductions* from new non-ZEV's replaced by new ZEV's purchased through the incentive program $[Step\ 5 * Step\ 6]$

$$GHG\ Reductions =\ ZEV\ eVMT * MPO\ \ Benefit\ Fraction * (Non\ ZEV\ EF - ZEV\ EF)$$

GHG Emission Reductions =	*GHG emission reductions from ZEV's purchased through the subsidy/rebate program g/d/veh*
ZEV eVMT =	*eVMT from ZEV's purchased through the subsidy/rebate program [Step 5] mi/d/veh*
MPO Electric Vehicle = Incentive Strategy Fraction	*Amount of GHG reductions MPOs may claim from the strategy if multiple rebate/incentive programs are utilized [Step 7]*
Non-ZEV EF =	*Average regional GHG emission factor from EMFAC for new-non-ZEVs [Step 6] g/mi*

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[97] If additional rebate or incentive programs in excess of the Electric Vehicle Incentive strategy (e.g., CVRP) are utilized, the MPO should not claim the entire GHG benefit, as GHG reduction benefits should be allocated between the multiple rebate or incentive programs based on their portion of the overall rebates provided. For example, if an MPO's Electric Vehicle Incentive strategy allocated $2,000 towards PHEV purchases and CVRP funding is also utilized, the MPO may only claim 57% of total CO_2 reductions from PHEV purchased through the Electric Vehicle Incentive strategy ($2,000 [MPO strategy incentive] ÷ $3,500 [MPO + CVRP strategy incentive] = 57% [MPO's portion of CO_2 reductions that may be claimed])

[98] MPOs should at least include the funding from California's CVRP (which is administered by Center for Sustainable Energy for CARB) $5,000 rebate for a purchase or lease of a fuel cell vehicle; $1,500 for PHEV; and $2,500 for BEV.

ZEV EF =	*Emission factor for new ZEV g/mi. For this strategy a battery electric vehicle is required to be purchased, thus the EF can be assumed to be 0 g/mi.*

Challenges, Constraints, and Strategy Implementation Tracking

Challenges and Constraints

- How will subsidies/rebates be distributed?
  - Point-of-sale
    - Requires more work for dealers, due to the responsibility of handling and submitting the incentive program paperwork and documentation, which may result in lower dealer participation
    - Requires less work for car buyers, which may result in higher program participation from consumers
  - After-purchase
    - Requires less work for dealers, which may result in higher dealer participation
    - Requires more work for consumers, due to the responsibility of obtaining, handling, and submitting the incentive program paperwork and documentation, which may result in lower program participation from consumers
- Rebate/subsidy prices
  - Should prices for rebates/subsidies be constant over time?
  - Should prices for rebates/subsidies change as prices change in the future?
- Are there prohibitions on the number of rebates/subsidies for which a consumer may qualify or a grace period before being eligible to qualify again?
- MPOs would need to set up program infrastructure that could require coordination with external entities
  - Coordinate with local dealers to educate, establish, and run incentive program
  - Coordinate with DMV to verify registration of new low-CO_2 vehicle prior to distribution of rebate to consumer
  - Coordinate with media partners to advertise the program to consumers
  - Coordinate with local air district(s) and other potential agencies to determine whether a coordinated effort would be feasible and could create a more effective program

- Potential for reaching larger consumer audience through larger outreach effort
- Potential for larger pool of total funding for incentive program if additional funding is available from non-MPO agencies[99]

Monitoring and Tracking

- Amount of total funding in program incentive program
- Amount of individual rebate/subsidies provided through the strategy
- Number of vehicles sold with rebates/subsidies
- Average regional VMT
- Average number of trips per day
- Average trip length
- Number of dealers participating
- Number of rebates/subsidies from each dealer
- DMV registration of new ZEVs purchased through the strategy

[99] In the event additional funding is available from non-MPO agencies, MPOs would only receive credit for GHG reductions pursuant to SB 375 for funds that are allocated explicitly for SB 375 GHG reductions and if non-MPO agencies do not claim GHG reductions for other purposes or programs (e.g., local air district incentive programs).

Transportation System Management (TSM)/Intelligent Transportation Systems (ITS)

Strategy Description

According to the United States Department of Transportation (USDOT), Intelligent Transportation System (ITS) is various technologies that advance transportation safety and mobility by integrating advanced communications technologies into transportation infrastructure and into vehicles.[100] Building upon the ITS technologies, Transportation System Management (TSM) specifically focuses on reducing traffic congestion by increasing the person-trip capacity of existing transportation system. In general, TSM/ITS refers to a broad range of strategies and technologies that aim to increase transportation system efficiency through congestion mitigation, traffic smoothing, and speed management, therefore, reducing GHG emissions. **Table 20** lists common examples of TSM/ITS related strategies.

Table 20. Examples of Common TSM/ITS Strategies

TSM	ITS
• Ramp metering • Restriping roadways for channelization • Arterial corridor management • Signal coordination • Intersection control	• Traveler information • Incident management • Connected vehicles • Autonomated vehicles

Given the many different TSM/ITS-related approaches to improve overall transportation system efficiency, MPOs need to clearly describe and identify the objectives of the specific strategies (e.g., increase overall system travel speed, reduce travel delay, etc.), and strategies for implementation to achieve these objectives.

Objectives

Generally, TSM/ITS can reduce GHG emissions by:

- Increasing system efficiency
- Optimizing travel speeds
- Alleviating congestion
- Promoting Energy-efficient driving

[100] United States Department of Transportation. *ITS Research Fact Sheets – Benefits of Intelligent Transportation Systems*. Available at: https://www.its.dot.gov/factsheets/benefits_factsheet.htm.

Trip and Emissions Data Needs

In addition to the general input data and assumptions for off-model strategies listed in **Table 13** of the introduction section, the following is a list of specific conditions and factors that contribute to improving vehicle speeds[101] that MPOs should consider and document for TSM/ITS strategies:

- What is the unit cost of implementation [e.g., cost per coordinated lane mile, cost per connected vehicle, cost per connected signalized intersection, and cost per traveler who utilizes the travel information site(s)]?
- What is the applicable time of day, current speed distribution/profile, signal timing plans for affected intersections/corridors, emission rates, VMT by speed bin, system delay?

Quantification Methodology

Since TSM/ITS covers a broad range of strategies to achieve GHG emission reductions through smoothing traffic, coordinating signal timing plans for corridors and/or arterials, or providing advance travel information for drivers or passengers, the following are general guidelines on the key analyses in quantifying the VMT and/or CO_2 emission reductions associated with TSM/ITS strategies. These steps serve as a guide for MPOs to document how the implementation of a particular TSM/ITS strategy will lead to improvements in travel speed and reductions in congestion and CO_2 emissions.

Step 1: Identify the amount of funding for a particular TSM strategy (F_{TSM})

Step 2: Identify the unit cost of installation and/or maintenance of the specific TSM-related system (C_{TSM})

Step 3: Calculate the approximate number of TSM-related system(s) (N_{TSM}) the given funding would allow.

$$N_{TSM} = \frac{F_{TSM}}{C_{TSM}}$$

N_{TSM} = *Number of TSM-related systems funded by strategy*

[101] Improving travel speed or relieving congestion can associate with lower GHG emissions from running or idling emissions.

F_{TSM} =	*Funding source(s) for TSM strategy supporting document for this parameter)*
C_{TSM} =	*Cost for TSM installation and maintenance*

Step 4: Gather the average hourly travel speed and VMT (*VMT*) of the affected roadway network.

Step 5: Based on the proposed number of and type of TSM-related systems, estimate the impact of the proposed TSM strategy to travel speed from empirical literature.

Step 6: Estimate the CO_2 emission factors for travel speeds with ($CO_{2\,TSM}$) without the effects of the TSM strategy ($CO_{2\,Pre}$) using the latest EMFAC model.

Step 7: Estimate the effects of the TSM strategy to CO_2 emissions.

$$CO_{2\,TSM\,Red} = (VMT * \ CO_{2\,TSM}) - (VMT * CO_{2\,Pre})$$

$CO_{2\,TSM\,Red}$ =	*CO_2 reductions from TSM strategy*
VMT =	*Affected roadway network VMT*
$CO_{2\,TSM}$ =	*Roadway travel speed EMFAC CO_2 emission factor with TSM*
$CO_{2\,Pre}$ =	*Roadway travel speed EMFAC CO_2 emission factor without TSM*

Challenges, Constraints, and Strategy Implementation Tracking

Challenges and Constraints

Besides quantification, MPOs should summarize known and foreseeable challenges in the implementation and operation of in-use and/or proposed TSM/ITS strategies. For example, the ongoing funding for the programs, coordination with local jurisdictions on synchronized signal timing for major corridors during peak hours, the possibility of overlapping with similar TSM strategies, the responsiveness of individual vehicles to connected vehicle technology, etc. Another challenge can be induced demand due to improved traffic speed on corridors that motivate travelers to drive more[102].

[102] Tools are available to help MPOs evaluate the effects of induced travel. Examples include, but are not limited to University of California, Davis National Center for Sustainable Transportation's Induced Travel Calculator, available at: https://blinktag.com/induced-travel-calculator/ and *Impact of Highway Capacity*

Monitoring/Tracking

For progress and effectiveness monitoring of TSM/ITS strategy, MPOs can consider conducting traffic surveys periodically to gather information on traffic speed by traffic lane or corridor, average hourly traffic at peak hours, average travel time for regular commuters, etc. Once this or other related data is collected, MPOs can update the initial analysis on the impact on reducing GHG emissions to track the effectiveness and performance of the strategy.

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and Induced Travel on Passenger Vehicle Use and Greenhouse Gas Emissions. October 2013. Available at: https://www.arb.ca.gov/cc/sb375/policies/hwycapacity/highway_capacity_brief.pdf.

Vanpool

Strategy Description

Vanpools strategies consist of strategies to decrease private automobile trips by transporting between 6 and 15 passengers in a single vanpool vehicle, rather than each passenger driving their own individual single occupancy vehicles.

In addition, vanpools decrease demand for parking, decrease single occupancy vehicle trips, and because most vanpools are for commute purposes, vanpools can help to decrease congestion during the am and pm commute periods when congestion is typically highest.

Objectives

Vanpool strategies can reduce GHG emissions as follows:

- Reducing commute-related vehicle trips
- Reducing commute-related VMT
- Improving peak hour congestion on travel corridors

Trip and Emissions Data Needs

In addition to the general input data and assumptions for off-model strategies listed in **Table 13** of the introduction section, the following is a list of specific conditions and factors that MPOs should consider and document for vanpool strategies:

- What are the average number of vanpool day(s) per worker for base and future analysis years?
- What are the available benefits for employer or employees to participate in a vanpool program?
- How can the strategy be incentivized to encourage and expand participation?
- What is the partnership and involvement of the MPO, local jurisdictions, agencies, and other stakeholders?
- What are the industries in the region that can participate in a vanpool program?
- Are there potential populations for vanpools for future RTP/SCS updates but currently not accounted for in the new RTP/SCS?

Trip Data

- What is the average travel distance for home-based worker commute trips in the region with and without vanpool?
- What is the average number of home-based worker commute trips per worker in the region with and without vanpool?

Quantification Methodology

If a vanpool strategy is considered by an RTP/SCS to reduce GHG emissions, the MPO needs to clearly describe the assumptions, quantification of GHG emission reductions, and implementation plan associated with the vanpool strategy that is in the proposed RTP/SCS (e.g., level of deployment, percent of workers that vanpool, industries that are affected by this strategy), and how this strategy will continue into the future to further reduce commute trip related VMT and/or GHG emissions.

The following lists the basic analytical steps an MPO can consider when quantifying GHG emission reductions from vanpooling.

Typically, CO_2 emission reductions from vanpool strategies are a result of VMT reductions due to mode shift from private automobile trips to vanpools, and VMT reductions are influenced by the effects of the vanpool strategy to ridership:

$$Vanpool\ Strategy \rightarrow Private\ Automobile\ Trip\ Reductions\ \rightarrow VMT\ Reduction \rightarrow CO_2\ Reduction$$

The overall approach is to determine the increase in number of full vans implemented by the vanpool strategy; estimating the number of private automobile trips shifted to vanpools; estimating average trip lengths for the region; obtaining necessary emission rates; and estimating net emissions associated with decreased private automobile operation (minus miles driven to the vanpool site), and new vanpool operation. Where available, region-specific data should be used in place of values listed herein.

Step 1: Calculate the number of full vans implemented by the strategy.

Step 2: Calculate the amount of private automobiles trips reduced annually based on the occupancy of vanpool vans. It is assumed one private automobile equals one vanpool passenger.

$$Auto\ Trips_{Red} = Vans * Van\ Occupancy$$

Auto Trips$_{Red}$ =	*Number of private automobile trips reduced by strategy*
Vans =	*Number of vans implemented by strategy*
Van Occupancy =	*Number of riders per van*

Step 3: Calculate the adjusted automobile miles traveled per trip. This formula takes into account the variability in driving behaviors of potential vanpool participants prior to the launch of the project, including the number of drivers that would

drive to a vanpool location and the number of vanpool riders that drive alone. If the "% Riders Driving Alone" value is unknown, 83% can be used,[103] which is suitable for long-distance, commuter vanpool services.

$$Miles/Trip_{Adj} = [\frac{Miles}{Trip} - (Vanpool_{\,Dist} * Vanpool_{\%})] * Single\ Riders_{\%}$$

$Miles/Trip_{Adj}$ =	*Adjusted miles per trip (miles/trip)*
$\frac{Miles}{Trip}$ =	*Average regional HW Trip Length (miles per trip)*
$Vanpool_{Dist}$ =	*Average distance vanpool riders drive to vanpool location (miles per trip)*
$Vanpool_{\%}$ =	*Percent of riders that drive to vanpool location (%)*
$Single\ Riders_{\%}$ =	*Percent of riders that drive alone (%)*

Step 4: Calculate total adjusted automobile VMT reduced

$$Auto\ VMT_{Red} = Auto\ Trips_{Red} * Miles/Trip_{Adj}$$

$Auto\ VMT_{Red}$ =	*Number of auto VMT reduced by strategy (miles)*
$Auto\ Trips_{Red}$ =	*Number of private automobile trips reduced by strategy (trips)*
$Miles/Trip_{Adj}$ =	*Adjusted miles per trip (miles/trip)*

Step 5: Obtain displaced private automobile trip CO_2 emission rates from the current version of EMFAC.[104]

Step 6: Calculate the CO_2 emissions of private automobile trips reduced by vanpool service trips

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[103] California Air Resources Board. *Methods to Find the Cost-Effectiveness of Funding Air Quality Projects*. May 2005. Available at: www.arb.ca.gov/planning/tsaq/eval/mv_fees_cost-effectiveness_methods_may05.doc.

[104] The Low Carbon Fuel Standards (LCFS) are assumed to not have a significant impact on CO_2 emissions from EMFAC's tailpipe emission estimates, as most of the emission benefits due to the LCFS come from the production cycle (upstream emissions) of the fuel rather than the combustion cycle (tailpipe). As a result, this analysis does not reflect any changes in CO_2 emissions associated with upstream activities (e.g., fuel refining, fuel transport, etc.) due to changes in fuel type and consumption associated with mode shift from private automobiles to transit.

$$CO_2 = Auto\ VMT_{Red} * EMFAC$$

Auto VMT_{Red} =	*Number of auto VMT reduced by strategy (miles)*
EMFAC =	*EMFAC CO_2 emission rate (grams per mile)*

Challenges, Constraints, and Strategy Implementation Tracking

Challenges and Constraints

- Locating safe areas for vanpool vehicle storage
- Implementing sufficient vanpool vehicles to accommodate potential user home and workplace locations
- Public outreach to draw suitable population
- Tracking use of strategy

Monitoring and Tracking

- The number of vans implemented by strategy
- Average van occupancy (maximum and average participation rate)
- Number of riders participating in program