Draft for Comments Only

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DRAFT PROPOSAL FOR UPDATED SUSTAINABLE COMMUNITIES STRATEGY PROGRAM & EVALUATION GUIDELINES

DECEMBER 2018

CALIFORNIA AIR RESOURCES BOARD

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Executive Summary of Proposed SCS Evaluation Guidelines

The California Global Warming Solutions Act of 2006, Assembly Bill (AB) 32 (Chapter 488, Statutes of 2006)[1] serves as the foundation for California's goals to reduce GHG emissions and is the basis for almost all of California's subsequent efforts to reduce GHG emissions. Building on the GHG emission reduction goals established under AB 32, Governor's Executive Order B-30-15 (2015) and SB 32 (Chapter 249, Statutes of 2016, Pavley) established more aggressive statewide GHG emission reduction goals (40 percent below 1990 levels by 2030) than were in place when SB 375 was passed in 2008. California recently updated its Climate Change Scoping Plan in 2017 to address these more aggressive reduction goals, and identified the need for greater GHG emission reductions from all sectors, including passenger vehicle travel and integrated land conservation and development strategies, of which Senate Bill (SB) 375 (Chapter 728, Statutes of 2008, Steinberg) is an integral part.

The California Air Resources Board (CARB or ARB) recently updated the SB 375 greenhouse gas (GHG) emission reduction targets (targets) that apply to the Regional Transportation Plans (RTP or Plan) prepared by the State's Metropolitan Planning Organizations (MPO) for the first time since the SB 375 program's inception. Those GHG emission reduction targets were increased for most of the MPOs from the original GHG emission reduction targets that were set in 2010, and the Board also directed staff to shift the way in which CARB staff evaluates each Plan pursuant to SB 375 GHG emission reduction targets. Specifically, the Board directed staff to place greater attention on the strategies, key actions, and investments committed by the MPOs and the jurisdictions they represent.

When SB 375 law was passed in 2008, CARB had limited experience reviewing RTPs. In 2011, CARB published its initial guidance describing its methodology for evaluating GHG emission reductions attributable to an SCS and determining SCS target achievement, *Description of Methodology for ARB Staff Review of Greenhouse Gas Reductions from Sustainable Communities Strategies Pursuant to SB 375*[2]. Drawing upon the technical expertise of CARB staff, the initial 2011 Guidance was drafted to focus on the technical aspects of the regional modeling and supporting analysis related to GHG quantification.

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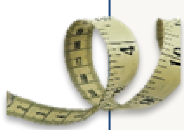
[1] CARB. California Global Warming Solutions Act of 2006, Assembly Bill (AB) 32 (Chapter 488, Statutes of 2006). September 2006. Available at: http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.pdf.

[2] CARB. Description of Methodology for ARB Staff Review of Greenhouse Gas Reductions from Sustainable Communities Strategies Pursuant to SB 375. July 2011. Available at: https://www.arb.ca.gov/cc/sb375/scs_review_methodology.pdf.

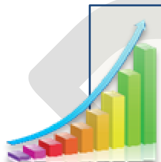
In the 10 years since passage of SB 375, CARB has reviewed over 20 SCSs. Through these reviews, CARB has gained additional insight and understanding of the MPOs' SCS development process. During this period, MPOs have also learned a great deal about SCS implementation, including barriers to implementation, and how SCS strategies reduce GHG emissions. In line with the Board's direction, CARB's goal is to set forth a Strategy-based SCS Program and Evaluation Framework, with more emphasis on the efforts MPOs are making to plan for more sustainable communities. CARB staff proposes to clarify the scope of the Strategy-based SCS Program and Evaluation Framework which includes the following four key areas – Tracking Implementation, Policy Commitments, Incremental Progress, and Equity (Figure 1).

Figure 1. New Strategy-Based SCS Program & Evaluation Framework



Tracking Implementation (Reporting Element):
Report on the progress regions have made towards meeting their SB 375 GHG reduction targets

Policy commitments (Determination Element):
Determine whether the strategies and commitments would achieve the GHG reduction targets, if implemented, and whether there are any risks to not achieving those reductions



Incremental Progress (Reporting Element):
Report on whether an MPO's proposed SCS has more or enhanced strategies than the currently adopted SCS

Equity (Reporting Element):
Report on the efforts MPOs are taking to meet federal and state requirements related to equity

CARB's Determination

CARB's statutory determination to accept or reject the MPOs determination that the SCS, if implemented, would achieve the assigned regional passenger vehicle GHG emissions reduction targets will be based on the element of the Policy Commitment analyses. Further, as directed by the CARB Board in its Resolution 18-12, approved on March 22, 2018 CARB's SCS program will also report on three additional elements including Tracking Implementation (SB 150 Reporting), Incremental Progress, and Equity. However, these elements will not be used for CARB's determination.

Tracking Implementation (SB 150 Reporting)

Recognizing the importance of realizing and measuring the benefits identified through the SB 375 planning work, the Legislature passed SB 150 in 2017 (Allen, Chapter 646, Statutes of 2017), which tasked CARB with analyzing the progress regions have made towards meeting their SB 375 GHG emission reduction targets, and to include data-supported metrics for strategies utilized to meet the targets pursuant to SB 375. SB 375 was adopted in 2008, and we have nearly arrived at the first milestone year for SB 375 GHG emission reduction targets (i.e., 2020) and are well on our way to 2035, the sunset year for the GHG emission reduction targets. Each region's actions to date over the last 10 years provide lessons learned, which will help MPOs ensure future plans are on track to meet regional GHG emission reduction targets, and other benefits the SCSs are expected to provide. Tracking implementation will be a reporting element of the proposed strategy-based SCS Program & Evaluation Framework.

Policy Commitments

Under SB 375, CARB is required to review an MPO's proposed methodology for estimating GHG emission reductions from their SCS, as well as the final quantification of GHG emission reductions. Based on this review, CARB must either accept or reject the MPO's determination that its SCS, if implemented, would achieve the assigned regional passenger vehicle GHG emission reduction targets. When assessing whether to accept or reject an MPO's SCS GHG emission reduction target determination, CARB staff will be assessing whether the region's strategies and commitments support the stated GHG reduction, and whether there are any risks to not achieving those reductions. The analysis will include elements CARB has used for prior SCS evaluations, but now include additional elements that assess whether there are supportive key actions[3] for the SCS strategies[4], including investments, and whether the

[3] as the specific activities that support or ensure successful implementation of the strategies
[4] as the land use and transportation goals and policies of the SCS

region is making plan adjustments, as necessary to meet the target, to account for changing conditions, including potential risks to achieving its land use and transportation goals. The Policy Commitments element will be the SCS determination element of the proposed strategy-based SCS Program & Evaluation Framework.

Incremental Progress

During the 2018 GHG emission reduction target update proceedings, a few MPOs reported to CARB that it will require even greater effort to achieve the same level of per capita GHG emission reductions reported in their current SCSs due to changes in factors outside of their control that are important determinants of travel behavior, such as the price of fuel, household income, and fleet efficiency. According to these MPOs, simply staying on course to achieve the previous SB 375 GHG emission reduction targets established in 2010 will be difficult to achieve with their current resources, let alone achieving the incrementally more aggressive GHG emission reduction targets adopted by the Board in 2018. CARB staff recognize that the MPOs are required to update assumptions in each RTP/SCS to be consistent with the latest available data and planning assumptions, which can either dampen or enhance the effects of their own VMT and GHG emission reduction strategies. To track this incremental progress, CARB staff will focus an element of its program on the efforts MPOs are taking to make progress from one plan to the next in terms of SCS strategies. CARB staff proposes a modeling-based or performance indicator-based approach to overcome the effects of assumptions and control for such factors outside the MPOs' control. This assessment will demonstrate to CARB that the MPOs are making an effort to achieve their GHG emission reduction targets through additional or enhanced strategies. It will also inform the next round of GHG emission reduction target setting for SB 375. This will be a reporting element of the proposed strategy-based SCS Program & Evaluation Framework.

Equity

AB 857 (Chapter, Statutes of 2002, Wiggins) established promotion of equity as a State planning priority alongside strengthening the economy, protecting the environment, and promoting public health and safety. During the 2018 regional GHG emission reduction target update proceedings, discussion from members of CARB's Board included a request that SCSs contain a "robust social equity analysis[5]". While the CARB Board

[5] J&K Court Reporting. Meeting of California Air Resources Board: Thursday, March 22, 2018. March, 2018. Available at: https://www.arb.ca.gov/board/mt/2018/mt032218.pdf?_ga=2.243746631.330498114.1544123257-322284002.1543529202.

Resolution (18-12) from the GHG emission reduction target update proceedings indicates the “[u]pdated [r]egional [t]argets will help incentivize the regions to implement more sustainable planning policies…which can provide…social equity benefits”, discussion from the CARB Board indicated the need to highlight efforts MPOs are taking to address equity.

The California Transportation Commission’s (CTC) *2017 Regional Transportation Plan Guidelines for Metropolitan Planning Organizations*[6] serves to help “[p]romote an integrated, statewide, multimodal, regional transportation planning process and effective transportation investments and [s]et forth a uniform transportation planning framework throughout California by identifying federal and state requirements and statutes impacting the development of RTPs.” With regards to the consideration of equity within RTPs, several federal and state legal requirements[7] protect low-income and minority populations, and the environmental justice and equity analysis requirements found in the RTP Guidelines are based on these requirements. As part of its program framework, CARB will report on the efforts MPOs are taking to meet the requirements of the RTP Guidelines related to equity, and this will be a reporting element of the proposed program strategy-based SCS Program & Evaluation Framework.

Resource Considerations

One of the challenges in developing guidelines for 18 MPOs across California is that one size does not fit all when developing GHG reduction strategies. These guidelines include CARB’s request for information/data that may be more readily available for some MPOs to provide than for others. Therefore, in order to account for differences in resources and capacity across MPOs, CARB is:

1) Streamlining the information for SCS review, which has resulted in fewer metrics being requested overall than in the prior Guidelines; and
2) Providing alternative assessments that CARB staff will conduct if an MPO does not have the resources to conduct the analysis itself.

[6] California Transportation Commission. January, 2017. *2017 Regional Transportation Plan Guidelines for Metropolitan Planning Organizations*. Available at http://www.dot.ca.gov/hq/tpp/offices/orip/rtp/docs/2017RTPGuidelinesforMPOs.pdf.

[7] Title 23 CFR Part 450.316(a); Title 42 U.S.C. Chapter 21 Section 2000(d) (Title VI of the federal Civil Rights Act of 1964); Title 49 CFR Part 21 (Title VI Regulations); portions of FTA Circular 4702.1B – Title VI Requirements and Guidelines for FTA Recipients; Presidential Executive Order 12898 on Environmental Justice (1994): portions of U.S. DOT Order 5610.2(a) (2012) and FHWA Order 6640.23A (2012); California Government Code Section 11135.

Guidelines Development and Next Steps

These draft guidelines are intended to help MPO's develop their SCSs and to provide consistency in CARB's Program and Evaluation of SCS's. The SCS evaluation process will inherently be flexible to account for variances in regional land use and transportation patterns, assumptions and inputs, appropriate strategies for emissions reductions, and data availability. In addition, this program comprises three reporting elements: Tracking Implementation, Incremental Progress, and Equity. CARB staff will use these guidelines to strive for effective, streamlined, and consistent evaluations that will best serve the requirements and mission of SB 375.

This draft proposal serves as the initial release of the updated approach to evaluating SCSs under the new SB 375 GHG emission reduction targets and, at this stage, is a living document. It is CARB staff's intent to continue stakeholder outreach to solicit and incorporate applicable stakeholder feedback into the final version. SCS development under SB 375 is a long-term iterative effort, as SB 375 requires CARB to update GHG emission reduction targets and MPOs to update their RTP/SCSs regularly. With each iteration, this program will continue to evolve as MPOs gain experience with SCS development. Likewise, CARB's review of SCSs will also be revised over time as new information become available. **Please provide comments to CARB staff by January 4, 2019 via email at SustainableCommunities@arb.ca.gov**. CARB staff expects to release the Final SCS Program & Evaluation Guidelines in February 2019.

I. Introduction and Background

Goals of SB 375

The Sustainable Communities and Climate Protection Act of 2008, Senate Bill (SB) 375, (Chapter 728, Statutes of 2008)[8] was enacted a decade ago and was the first-of-its-kind State law recognizing the importance of integrating planning for land use, transportation, and housing to support climate objectives. The law created a new collaborative planning framework between the State and its regional MPOs, as well as between the MPOs and their local member agencies. This collaborative framework requires strategies be identified in the SCS for the purposes of reducing per capita GHG[9] emissions from passenger cars and light duty trucks that would ultimately lead to healthier, more efficient, and equitable communities.

SB 375 serves to implement changes at the policy and planning level that can improve several determinants of community health and sustainability. Thoughtful integration of land use, transportation, and housing planning and corresponding investments lead to improved access to employment, housing, food, health care, community services, and amenities. In addition to the numerous social, economic, and public health benefits, more integrated planning under SB 375 has the potential to strengthen resilience to disasters and changing climate, and is central to meeting the State's climate and air quality goals.

Federal Planning Context

Under federal law, Fixing America's Surface Transportation Act, MPOs are required to develop and adopt an RTP covering a minimum 20-year planning period and updated every four years.[10] The requirements for RTP development are outlined in the federal *Final Rule* on Statewide and Nonmetropolitan Transportation Planning and Metropolitan Transportation Planning and are codified in Title 23 Code of Federal Regulations (CFR) Part 450 and 771 and Title 49 CFR Part 613. Under federal law, RTPs must consider the following federal planning factors:

- Support the economic vitality of the metropolitan area, especially by enabling global competitiveness, productivity, and efficiency;

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[8] CARB. Sustainable Communities and Climate Protection Act of 2008, Senate Bill (SB) 375, (Chapter 728, Statutes of 2008). September 2008. Available at: http://www.leginfo.ca.gov/pub/07-08/bill/sen/sb_0351-0400/sb_375_bill_20080930_chaptered.pdf.

[9] Throughout these guidelines, GHG and carbon dioxide (CO_2) may be referenced interchangeably. The adopted GHG emissions reduction targets are reported in units of percent reduction in pounds per capita per weekday of CO_2 emissions with reference to 2005 levels.

[10] See 23 U.S.C. § 134.

- Increase the safety of the transportation system for motorized, and non-motorized users;
- Increase the security of the transportation system for motorized and non-motorized users;
- Increase accessibility and mobility of people and freight;
- Protect and enhance the environment, promote energy conservation, improve the quality of life, and promote consistency between (regional) transportation improvements and State and local planned growth and economic development patterns;
- Enhance the integration of connectivity of the transportation system across and between modes, for people and freight;
- Promote efficient system management and operation;
- Emphasize the preservation of the existing transportation system;
- Improve the resiliency and reliability of the transportation system and reduce or mitigate storm water impacts to surface transportation; and
- Enhance travel and tourism.

In addition to the factors that must be considered above, and among other requirements, MPO RTP/SCSs are required to comply with the Civil Rights Act of 1964. Title VI of the Civil Rights Act of 1964 ensures that all people have equal access to the transportation planning process. Title VI states: all people regardless of their race, sexual orientation, or income level, will be included in the decision-making process.

Additional information regarding the federal requirements for the RTP/SCS can be found in the CTC's *2017 Regional Transportation Plan Guidelines for Metropolitan Planning Organizations*.[11]

[11] California Transportation Commission, 2017 Regional Transportation Plan Guidelines for Metropolitan Planning Organizations, Adopted by CTC on 18 January, 2017. Available at: http://www.dot.ca.gov/hq/tpp/offices/orip/rtp/docs/2017RTPGuidelinesforMPOs.pdf

State Planning Context

Passed in 2006, the California Global Warming Solutions Act of 2006, AB 32 (Chapter 488, Statutes of 2006)[12] serves as the foundation for California's goals to reduce GHG emissions and is the basis for almost all of California's subsequent efforts to reduce GHG emissions. Building on the GHG emission reduction goals established under AB 32, Governor's Executive Order B-30-15 and SB 32 (Chapter 249, Statutes of 2016) established more aggressive statewide GHG emission reduction goals (40 percent below 1990 levels by 2030) than were in place when SB 375 originated in 2008. California recently updated its *Climate Change Scoping Plan in 2017*[13] to address these more aggressive GHG emission reduction targets, and identified the need for greater GHG emission reductions from all sectors, including passenger vehicle travel, and integrated land conservation and development strategies, of which SB 375 is an integral part.[14]

As stated in SB 375 "[w]ithout improved land use and transportation policy, California will not be able to achieve the goals of AB 32."

Regional Planning Context

The MPO is charged with transportation planning at the regional level. Thus, MPOs were created to develop strategies for operating, managing, maintaining, and financing the area's transportation system in a way that advances the region's long-term goals through collaboration with local jurisdictions. Transportation planning and land use planning became even more closely linked in California following the passage of SB 375. SB 375 requires each MPO to adopt an action-oriented SCS, which is an integrated land use, housing, and transportation plan that is part of each MPO's federally required RTP.

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[12] CARB. California Global Warming Solutions Act of 2006, Assembly Bill (AB) 32 (Chapter 488, Statutes of 2006). September 2006. Available at: http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.pdf.

[13] CARB, California's 2017 Climate Change Scoping Plan. November 2017. Available at: https://www.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf.

[14] CARB. The 2017 Climate Change Scoping Plan Update: The Proposed Strategy for Achieving California's 2030 Greenhouse Gas Target. January, 2017. Available at: https://www.arb.ca.gov/cc/scopingplan/2030sp_pp_final.pdf.

The State and MPOs prepare growth projections as to how much long-range population and employment growth is expected across the State as a whole, and within each region. The amount of growth projected in each region will invariably be accompanied by the need for mobility and use of the transportation system. In other words, by accommodating growth, a region commits to adding some increment of personal vehicle miles traveled (VMT) and associated GHG emissions. SB 375 acknowledges that ***where*** and ***how*** that growth occurs matters. SB 375 requires that a region's growth in coordination with the planned transportation system occur in a way that, if implemented, reduces regional per capita GHG emissions compared to year 2005 levels according to respective GHG emission reduction targets adopted by CARB.

Where and *how* growth occurs matters.

CARB is responsible for setting each MPO region's GHG emission reduction targets, and updating them at least every eight years. The law includes requirements for a technical methodology exchange and review between each MPO and CARB prior to starting the SCS public participation process. To the extent an MPO's SCS is unable to demonstrate it would, if implemented, achieve the GHG emission reduction targets set by CARB, the law requires the MPO to prepare an Alternative Planning Strategy (APS) to the SCS demonstrating how the GHG emission reduction targets would be achieved. CARB is required to review each MPOs' final adopted SCS, or APS if applicable, to determine whether the SCS, if implemented, would achieve the GHG emission reduction targets. If CARB finds that the MPOs' SCS or APS would not achieve its targets, the MPO must revise it, with a minimum requirement that the MPO receive CARB acceptance that an APS, would achieve the GHG emission reduction targets. Further detail on roles and responsibilities in this process, as specified by statute, are discussed below.

MPO Roles and Responsibilities under SB 375

CARB staff and MPO staff have developed a strong practice of collaboration over the last ten years in support of SCS evaluations under SB 375. CARB staff appreciates the longstanding commitment of staff resources that MPOs have allocated to working with CARB on SCS evaluations. As an MPO develops its RTP/SCS, an information exchange between CARB and the MPO exists throughout the process.

Technical Methodology Submittal

Prior to starting the statutory public participation process for development of an SCS, SB 375 requires that an MPO must first submit a Technical Methodology to CARB for review that describes the methodology the MPO intends to use to estimate the GHG emission reductions associated with its SCS.[15]

SCS Development and Submittal

SB 375 requires MPOs to create an SCS, which is an action-oriented plan that aligns financially constrained regional transportation investments, housing, and land use planning.[16] The SCS includes specific planned or enacted strategies and investments identified by the MPO that describe how the region will achieve the regional GHG emission reduction targets set by CARB. These strategies are typically evaluated in the MPO's travel demand model, which consist of computer-based calculation tools used to forecast future travel based on simulations of complex interactions among demographics, land use development patterns, transportation infrastructure, and other related factors. Federal and state requirements for MPO models are documented in CTC's *2017 Regional Transportation Plan Guidelines for Metropolitan Planning Organizations*.[17] In the event the MPO's travel demand model does not have sufficient resolution, nor sufficiently robust, to characterize the effects of an MPO's strategy, SB 375 allows for the use of off-model tools and other approaches to characterize the effectiveness of a strategy.

CARB Roles and Responsibilities under SB 375 and SB 150

GHG Emission Reduction Targets

CARB's first role under SB 375 is to set and revise the GHG emission reduction targets at least every eight years for each MPO in the State. On September 23, 2010, the CARB Board approved 2020 and 2035 per capita GHG emission reduction targets for each of the 18 MPO regions, as required by SB 375.[18] Subsequently, CARB developed guidance for MPOs in 2011 describing its methodology for evaluating GHG emission reductions attributable to an SCS and determining SCS target achievement, *Description of Methodology for ARB Staff Review of Greenhouse Gas Reductions from Sustainable*

[15] Gov. Code § 65080, subdivision (b)(2)(J)(i).
[16] Gov. Code § 65080, subdivision (b)(2)(B).
[17] California Transportation Commission, 2017 Regional Transportation Plan Guidelines for Metropolitan Planning Organizations, Adopted by CTC on 18 January, 2017. Available at: http://www.dot.ca.gov/hq/tpp/offices/orip/rtp/docs/2017RTPGuidelinesforMPOs.pdf
[18] Gov. Code § 65080, subdivision (b)(2)(A).

Communities Strategies Pursuant to SB 375[19]. CARB updated the GHG emission reduction targets in March 2018, and those new targets took effect in October 2018.[20]

Technical Methodology Review

As previously indicated, MPOs must submit a Technical Methodology to CARB for review prior to the MPO's statutorily required RTP public participation process. Upon receipt of the Technical Methodology, CARB staff initiate their review to ensure the proposed methodology would yield accurate estimates of GHG emissions, identify any potential deficiencies, and suggest recommendations for improvements to the MPO's Technical Methodology. This can be an iterative process as MPOs and CARB work to address any questions, concerns, and recommendations CARB may have. If CARB's review deems the Technical Methodology adequate, CARB then provides the MPO with a formal letter of acceptance. If CARB determines that the proposed Technical Methodology would not likely yield accurate estimates of GHG emissions from the SCS, the MPO is encouraged to work with CARB to revise the proposed Technical Methodology until it is acceptable.

SCS Review

The MPO's Final adopted SCS is submitted to CARB for review upon adoption.[21] CARB must review the MPO's quantification of GHG emission reductions as well as the MPO's description of the Technical Methodology used to quantify the SCS's GHG emission reductions. Based on this review, CARB must either accept or reject the MPO's determination that its SCS, if implemented, would achieve the assigned regional GHG emission reduction targets. CARB has 60 days to complete its determination[22].

Monitoring and Tracking under SB 150

In 2017, SB 150 was enacted and requires CARB, in consultation with the MPOs and affected stakeholders, to develop a report for the Legislature beginning September 1, 2018, and every four years thereafter, that assesses the progress made by each MPO in meeting the regional GHG emission reduction targets set by CARB.[23] The report is required to include changes to GHG emissions in each region and data-supported

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[19] CARB. Description of Methodology for ARB Staff Review of Greenhouse Gas Reductions from Sustainable Communities Strategies Pursuant to SB 375. July 2011. Available at: https://www.arb.ca.gov/cc/sb375/scs_review_methodology.pdf.

[20] CARB. Proposed Update to Senate Bill 375 Greenhouse Gas Emission Reduction Targets (Resolution 18-12). Available at https://www.arb.ca.gov/cc/sb375/finalres18-12.pdf

[21] Gov. Code § 65080, subdivision (b)(2)(J)(ii).

[22] ibid.

[23] Gov. Code § 65080, subdivision (b)(2)(J)(iv).

metrics for the strategies utilized to meet the GHG emission reduction targets. The report is also required to include a discussion of best practices and the challenges faced by the MPOs in meeting GHG emission reduction targets, including the effect of state policies and funding.

II. Why is CARB Updating the SCS Program & Evaluation Guidelines?

There are mainly two drivers that make it necessary to update the way in which CARB evaluates SCSs: to respond to Board direction to shift focus in the SB 375 program, and address shortcomings with the current process based on lessons learned from prior SCS reviews.

CARB recently updated the GHG emission reduction targets for the first time in March 2018, with an effective date of October 1, 2018. At that time, the CARB Board increased the GHG emission reduction targets for most of the MPOs from the original targets that were set in 2010, and also directed[24,25,26] staff to shift direction in the way in which CARB staff evaluates each SCS pursuant to SB 375 targets. As noted above, SB 150 enacted in 2017 also directed CARB to examine and report to the Legislature on evidence of on-the-ground progress and impacts of policy change on GHG emission reductions. In other words, the Legislature requested a conclusion about whether the SCSs are achieving their GHG emission reduction targets, and if not, an assessment of the obstacles to their achievement.

As further background, after SB 375 was initially adopted and the first set of GHG emission reduction targets were established for the 18 MPOs, CARB published its initial SCS guidelines in 2011 describing their methodology for determining SCS GHG emission reduction target achievement. This includes four key components, such as model inputs and assumptions, modeling tools, model sensitivity tests, and performance indicators. That methodology has been used exclusively over the last eight years to review over 20 SCSs, and is focused on the capabilities, performance, input assumptions, and accuracy of MPOs’ land use and travel demand models. This is because CARB’s expertise with RTPs when their initial 2011 SCS guidelines were published was primarily technical in nature and based upon their expertise with the interplay between travel demand models and GHG quantification methods. Models are one tool for measuring RTP/SCS performance, but alone are limited in what they can tell us about the SCS.

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[24] Resolution adopted by CARB Board on March 22, 2018. CARB Final Resolution 18-12. Available at https://www.arb.ca.gov/cc/sb375/finalres18-12.pdf

[25] CARB, Updated Final Staff Report: Proposed Update to the SB 375 Greenhouse Gas Emission Reduction Targets, 2018. Available at https://www.arb.ca.gov/cc/sb375/sb375_target_update_final_staff_report_feb2018.pdf

[26] J&K Court Reporting. Meeting of California Air Resources Board: Thursday, March 22, 2018. Available at: https://www.arb.ca.gov/board/mt/2018/mt032218.pdf?_ga=2.243746631.330498114.1544123257-322284002.1543529202

Based on feedback from the MPOs and stakeholders over the years, CARB needs to address a variety of shortcomings in the review methodology including, lack of transparency in the CARB SCS review process, lack of clarity on the information exchange process and expectations between MPOs and CARB, and lack of guidance and standardized approaches to GHG emissions quantification and MPO data submittals.

CARB recognizes that an MPOs plan performance is dependent not only on things MPOs can control (their policies and investments), but things that they do not control (such as changes to forecasted demographics, fuel price, fleet mix, etc.) as well. In practice, this has resulted in an unproductive effort focused around assumptions for factors outside of any regional or State agency's control. In addition, dduring the 2018 GHG emission reduction target update process, the MPOs reported to CARB that, due to changes in factors beyond their control, it will require even greater effort to achieve the same level of per capita GHG emission reductions reported in their current SCSs. As a result, CARB is including an additional reporting element to assess incremental progress in the next planning cycle.

III. What are CARB's Goals for Updating the SCS Program & Evaluation Guidelines?

To address the needs discussed above, CARB is implementing a new direction in the way it evaluates SCSs moving forward, including monitoring progress as part of the SB 150 reporting requirement. CARB staff aims to focus its evaluation more squarely on the strategies, policies, and investments in the plans. In addition, CARB will be incorporating reporting elements that won't be part of CARB's determination, but are important to the program. Specifically, this draft proposal attempts to improve the scope of the SCS Program and Evaluation to include the following:

Incorporate Board direction[27,28,29] into the SCS Program Framework:

- Increase focus on land use and transportation strategies and evaluate how these strategies are performing in the Plan;
- Increase analysis of the investments and strategies MPO regions are making as compared to the last SCS. This enhanced assessment broadens the SCS review framework: **Policy Commitments**;
- Increase program transparency and accountability through the development of additional reporting and tracking guidance within the SCS Program Guidelines. This additional guidance for reporting and tracking includes the addition of two new elements to the SCS review framework: **Increment of Progress** evaluation and **Tracking Implementation**.
- Address **Equity** as part of the program by reporting the efforts MPOs are taking as part of their social equity analyses.

Make improvements to CARB's SCS review process:

- Clarify expectations to MPOs and stakeholders about CARB's SCS review process;
- Provide more transparency and consistency in how CARB conducts SCS reviews;
- Better align the timing and content of MPO modeling and data submittals with the CARB SCS review process;

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[27] Resolution adopted by CARB Board on March 22, 2018. CARB Final Resolution 18-12. Available at https://www.arb.ca.gov/cc/sb375/finalres18-12.pdf

[28] CARB, Updated Final Staff Report: Proposed Update to the SB 375 Greenhouse Gas Emission Reduction Targets, 2018. Available at https://www.arb.ca.gov/cc/sb375/sb375_target_update_final_staff_report_feb2018.pdf

[29] J&K Court Reporting. Meeting of California Air Resources Board: Thursday, March 22, 2018. Available at: https://www.arb.ca.gov/board/mt/2018/mt032218.pdf?_ga=2.243746631.330498114.1544123257-322284002.1543529202

- Clarify and consolidate data requested by CARB staff to minimize ad-hoc requests to MPO staff during the SCS evaluation.

Provide guidance and standardize approaches to GHG emissions quantification and MPO data submittals:

- Identify common consistent approaches for MPOs to estimate GHG emission reductions by outlining the key technical aspects that underlie GHG quantification and methodologies[30];
- Establish clear guidelines on what MPOs should submit to CARB;
- Clarify expectations around level of detail and resolution of data submitted by MPOs to CARB;
- Identify a common set of performance metrics that MPOs should report to CARB for SB 150 tracking SCS implementation over time.

Purpose of this Report

The purpose of this document is to present CARB's recommendations to update our SCS Program and Evaluation Guidelines to solicit public input from MPOs and affected stakeholders. CARB's recommended updates to the SCS Evaluation and Program Guidelines are guided by the legislative authority granted to CARB by SB 375 to establish appropriate methods for technical review of an SCS, directives from the CARB Board, updates to SB 375, and lessons learned from conducting nearly a decade of SCS reviews. These updated guidelines will apply only to the MPOs third SCSs, and will be updated again before the fourth SCSs are developed.

These updated guidelines will apply only to the MPOs third SCSs, and will be updated before the fourth SCSs are developed.

This proposal is intended primarily for stakeholders who are already familiar with the existing *Description of Methodology for ARB Staff Review of Greenhouse Gas Reductions from Sustainable Communities Strategies Pursuant to SB 375*[31] and its requirements. Additional background information about CARB's current methodology for reviewing GHG emission reductions for an SCS and related materials, including

[30] Note: MPOs have discretion in the methodologies used to quantify GHG emissions within their respective SCSs. All methodologies used must be documented in the respective MPO's technical methodology and should be shared with CARB in advance of the statutorily required public comment period.
[31] California Air Resources Board. Description of Methodology for ARB Staff Review of Greenhouse Gas Reductions from Sustainable Communities Strategies Pursuant to SB 375. July 2011. Available at: https://www.arb.ca.gov/cc/sb375/scs_review_methodology.pdf.

regional GHG emission reduction targets, CARB Staff Reports, and previous MPO SCSs and CARB technical reviews, are found online at https://ww2.arb.ca.gov/resources/documents/scs-evaluation-resources.

IV. What is CARB looking for in an SCS?

The proposed strategy-based SCS Program and Evaluation framework consists of four components that, when taken together, give CARB staff the full picture of the regions' strategies and how they will achieve the GHG emission reduction targets.

- **Tracking Implementation (Reporting Element):** Report the progress of strategies that the regions have made towards meeting their SB 375 GHG emission reduction targets to assess whether the strategies are being implemented, and how well strategies are working.
- **Policy Commitments (Determination Element):** Evaluate an SCS's land use and transportation strategies and their likelihood or tendency toward reducing VMT and GHG emissions consistent with the MPOs determination; evaluate potential risks to SCS strategies and associated impact on reducing per capita GHG emissions and VMT.
- **Incremental Progress (Reporting Element):** Report the incremental progress from the proposed SCS against the previous SCS, and report on whether MPOs are making incremental progress consistent with information shared during the 2018 GHG emission reduction target setting process[32].
- **Equity (Reporting Element):** Report on the efforts MPOs are taking to meet federal and state requirements related to equity.

CARB has enhanced the SCS program and evaluation framework to include a new component to **track implementation**. This allows CARB staff to compare progress against SCS performance benchmarks to understand the progress regions have made towards meeting their targets, and how well strategies are working. Some MPOs have indicated that they will provide an RTP/SCS implementation assessment report for this element that describes the implementation status of adopted RTP/SCS strategies.

The evaluation of modeling assumptions and tools will not be the central focus of CARB's SCS evaluation, however, it will still remain as one consideration in how the SCS meets the GHG emission reduction targets. If the MPO's validate and calibrate their models to meet the applicable requirements of the RTP Guidelines, then the model is considered valid. CARB staff will continue to collect information about the sensitivity of the modeling tools used by the MPOs to determine whether they are capable of reflecting the stated SCS strategies and producing correspondingly sound results. CARB staff aims to make this process more consistent and transparent across MPOs.

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[32] CARB, Updated Final Staff Report: Proposed Update to the SB 375 Greenhouse Gas Emission Reduction Targets, February, 2018. Available at https://www.arb.ca.gov/cc/sb375/sb375_target_update_final_staff_report_feb2018.pdf

CARB staff will perform a **policy commitments** analysis to verify the SCS strategies are supported by policies and investments that yield the projected changes in VMT, land use patterns, mode share, and other metrics that are consistent with the per capita GHG emission reductions identified in the SCS. CARB staff will assess whether the performance indicators are trending in a direction that supports GHG emission reductions and whether the magnitude of the stated GHG emission reductions are generally supported by empirical literature and data. In addition, if the region is falling behind on implementation of strategies, CARB will also assess what measures are being taken to correct course, as necessary to meet the target, and get the plan back on track.

CARB staff is also assessing **incremental progress** in per capita GHG emissions reductions from one plan to the next, as applicable. During the 2018 GHG emission reduction target update process some MPOs reported to CARB that due to changes in factors beyond their control, it will require even greater effort to achieve the same level of per capita GHG emission reductions reported in their current SCSs. According to these MPOs, simply staying on course to achieve the previous SB 375 GHG emission reduction targets established in 2010 will be a stretch of their current resources, let alone achieving the more aggressive targets adopted by the Board in 2018. In order to continue to meet their SB 375 GHG emission reduction targets, the MPOs are left to make up their respective gaps through additional innovation and strategies that reduce GHG emissions. Thus, in order to demonstrate to CARB that the MPOs are, in fact, stretching to achieve their GHG emission reduction targets, this portion of the evaluation will focus more squarely on the strategy commitments MPOs are making from one plan to the next.

Finally, **equity** is included as a reporting element of the SCS Guidelines, and CARB staff will report whether MPOs are conducting equity analysis as part of their SCS. This equity reporting will focus on the MPO’s identification of vulnerable communities within their jurisdiction, the metrics and performance measures identified by MPOs to ensure no disproportionately high and adverse effect on human health and environment, the types of qualitative and quantitative equity analyses conducted by MPOs, and the stakeholder engagement process established by MPOs.

The contents of each element are further described in the subsequent sections of this report.

V. Strategy-Based SCS Program and Evaluation Framework

The purpose of CARB's strategy-based SCS Program and Evaluation Framework is to enhance transparency and accountability of strategies within the plan, and to determine whether the proposed strategies support the calculated GHG emission reductions from the overall plan. CARB staff recognizes that California's 18 MPOs represent a wide variety of land use types, transportation systems, population centers, and development patterns. 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. To account for these differences and to gain a better understanding of what is occurring within the region, the strategy-based SCS Program and Evaluation will be conducted through the assessments mentioned above, many of which are already part of the existing SCS evaluation methodology.

For reference, CARB staff classifies SCS strategies into five broad categories: housing and employment (land use), public transit and active transportation, local/regional pricing, vehicle technology/innovative mobility, and Transportation System Management Transportation Demand Management (TSM/TDM). Table 1 provides a non-exhaustive list of examples of SCS strategy types and key actions for which MPOs can take credit under SB 375, and the presence of which CARB staff will evaluate. Within these guidelines CARB staff refer to "strategies" as the land use and transportation goals and policies of the SCS, broadly; and "key actions" as the specific activities that support or ensure successful implementation of the strategies.

Table 1. SCS Strategy and Key Action Examples

Strategy Category	Strategy Examples	Key Action Examples
Housing and Employment (land use)	Infill development, increased multi-family and/or small lot development, increased densities for residential and commercial development, transit-oriented development, increased jobs/housing balance/fit, etc.	MPO funds allocated to update local plans and zoning to increase density in targeted areas.
Public Transit and Active Transportation	Increased transit operations and efficiency, bike and pedestrian infrastructure, bikeshare systems, complete streets policies, etc.	Electronic fare payment system recognized across mobility providers.
Local/Regional Pricing	High-occupancy toll (HOT) lanes, local/regional congestion pricing, road user fees, variable parking pricing, etc.	Non-regressive fee structure or rebates to alleviate disproportionate impacts to low-income groups.
Vehicle Technology/ Innovative Mobility	Electric vehicle (EV) charging infrastructure, connected and autonomous vehicle technology, dynamic ride-hailing and ridesharing,	Subsidize shared/pooled transportation network company (TNC) rides and/or subsidize TNC trips that begin/end at a transit station.
Transportation System Management (TSM) Transportation Demand Management (TDM)	Intelligent Transportation System (ITS), Telecommuting, trip reduction programs, carpooling/vanpooling, traffic calming, signal synchronization, etc.	MPOs incentivize trip reduction programs or vanpool

VI. What type of information and data does CARB need from the MPO to conduct the Strategy-Based SCS Program and Evaluation?

The following section describes what type of information/data CARB staff needs from the MPO to evaluate an SCS. However, if an MPO does not have specific land use and transportation network attributes identified in this section of the report, they can also provide alternative attributes that represents the given SCS strategies.

Land Use and Transportation Attributes and Performance Indicators

MPO should submit the following **land use- and transportation -related attributes** for the SCS for 2005, plan base year, 2020, 2035, and plan horizon year. These “attributes” represent many SCS strategies, and are indicators of how the region aims to change over time.

Land Use Attributes

- Residential densities (total regional and by place type or sub-regional geography as defined by respective MPO)
- Employment densities (total regional and by place type or sub-regional geography as defined by respective MPO)
- Total regional housing product type/mix (single-family/multi-family)
- Total regional developed acres
- Total housing units and employment within ½ mile of a High-Quality Transit Station

Transportation Attributes

- Lane miles of roadway by functional classification
- Transit headways
- Transit operation miles
- Transit service hours
- Class I, II, and IV bike lane miles
- Average toll rate/congestion pricing per unit

The combination of land use and transportation network attributes (i.e., strategies) should lead to performance outcomes that demonstrate VMT and associated per capita GHG emission reductions. For more information on each attribute and performance indicator, including a description and methodology for calculating, see Appendix C. The MPOs should report the following strategy **performance indicators** for 2005, base year, 2020, 2035, and plan horizon year:

Because these performance indicators will be central to CARB staff's new evaluation framework regarding whether the SCS meets the SB 375 targets, MPOs are encouraged to publicly report these indicators as early as possible in their SCS scenario development process.

Strategy Performance Indicators (Outcomes):

- Household vehicle ownership
- Mode split
- Average travel time by mode
- Transit ridership
- Average vehicle trip length
- Seat utilization
- Household VMT/capita (external-external [XX] trips excluded)
- GHG/capita

Because these performance indicators will be central to CARB staff's new evaluation framework regarding whether the SCS meets the SB 375 GHG emission reduction targets, MPOs are encouraged to publicly report these indicators as early as possible in their SCS scenario development process.

The MPOs should also submit the following information:

- MPO's adopted **land use allocation** (or forecasted development pattern) (total new population growth, housing growth, and employment growth) tabulated by place type or sub-regional geography as appropriate to each region.
- MPO's adopted **transportation project list,** including project costs, funding source (if known/available), project time period (e.g., base year through 2020, 2020 through 2035, or after 2035), and project locations, in Excel format.

For the land use allocation, MPOs may use sub-regional definitions that are currently available within their plan (e.g., place type) or develop new definitions suitable for classifying where new growth is planned. For example, MPOs may use political boundaries (incorporated cities, unincorporated areas), or place types such as urban, suburban, rural, existing community, developing community, and/or Transit Priority Area (TPA) or High-Quality Transit Areas (HQTA) as the sub-regional geographic definition, or a combination of both. The minimum appropriate resolution is the resolution necessary to convey how strategies are implemented to achieve the stated outcomes. For example, if increasing density around existing transit corridors is the MPO's key land use strategy, then the MPO, where feasible, should define a land use category or place type that represents the existing transit corridors.

The minimum sub-regional resolution is the resolution necessary to convey how strategies are implemented to achieve the stated outcomes.

CARB encourages MPOs to submit their land use allocation at the highest resolution available. An example format for the land use allocation submittal is provided below in Table 2.

Table 2. Example Land Use AllocationError! Reference source not found.
See Section VII. MPO-CARB Information Exchange for a comprehensive summary of the MPO data submittal elements and timing.

How does CARB use this data?

CARB will conduct four types of assessments using the SCS attributes and performance indicators to help answer the following questions:

Tracking Implementation (Reporting Element)

- Report the performance of strategies that the region has made towards meeting their GHG target. Is the region following through on its strategy commitments from the previous SCSs? Is the region meeting, or on track to meet, its targets? What barriers exist?

Policy Commitments (CARB Determination Element)

- Assess whether the strategies and commitments support the stated GHG reductions, and whether there are any risks to not achieving those reductions.
  This element will be comprised of the following five analyses:
- **1) Trend Analysis:** Do the data show that the plan is moving a direction consistent with the planned outcomes, including the planned regional GHG reductions?
- **2) Elasticity Analysis:** Does the scientific literature support the stated GHG emissions reductions?
- **3) Policy Analysis:** Are there supportive key actions for the SCS strategies?
- **4) Investment Analysis:** Do the investments support the stated GHG emissions reductions or key actions?
- **5) Plan Adjustment Analysis:** If the region is falling behind on implementation, what measures are the MPO taking to correct course in the plan, as necessary, to meet the target?

Increment of Progress (Reporting Element)

- Report on whether an MPO's proposed SCS has more or improved strategies than the currently adopted SCS. Is this SCS achieving greater reductions due to strategies compared to the last SCS, and consistent with information the MPO shared during the 2018 target setting process?

Equity (Reporting Element)

- Report on the efforts MPOs are taking to meet federal and state requirements related to equity.

CARB staff is also looking to the land use allocation to understand how the MPO envisions the proportion of new growth that gets directed toward existing communities and infill areas served by existing transportation infrastructure relative to greenfield areas. Where and how new growth is accommodated is the heart of the SCS's land use strategy.

CARB staff will use the transportation project list information to sort transportation investments by project type, mode, cost, timing, and/or geography when available to better understand the location and type of investment priorities, how and where investments are being distributed in the region relative to new growth. The transportation project list and the land use allocation will be primarily used to support the Policy Analysis portion of CARB staff's evaluation.

Tracking Implementation (SB 150 Reporting)

Because SCSs are long-term plans covering multiple decades, a significant amount of effort to date has been spent forecasting where we might be in the future, while less effort has been spent looking back to assess progress. To assure future success, CARB staff will start tracking whether the strategies in the SCSs are being implemented (e.g. on-the-ground changes, permits issued, investments spent), and how well they are working. With this information, we can better understand if we are on trajectory to meet the GHG emission reduction targets, and how we might adjust course if we are not.

CARB staff published the first-of-its-kind assessment in November 2018 to take stock of what progress has occurred under SB 375 to date, pursuant to SB 150 (Chapter 646, Statutes of 2017). Per the statute, CARB must assess each region's progress on achieving regional GHG emission reduction targets as well as on metrics for the strategies being used to meet the targets, best practices, challenges, and the impacts of state policies and funding and report to the Legislature every four years.

CARB staff will be building off the work done for the first report to the Legislature on SB 375 implementation by reporting the level of implementation of individual SCSs through our evaluation process. The goal of tracking implementation section is to answer the following questions:

- Is the region meeting, or on track to meet, its RTP/SCS performance benchmarks?
- Are key regional metrics tracking with the expectations set out in previous SCSs?

CARB staff will begin reporting on whether the region is following through on its strategy commitments in the previous SCS, by comparing observed data with projections provided by the MPO from the previous SCS for key plan performance benchmarks such as multi-family housing units, miles of bike lanes, and improvements to transit service to see if the region implemented projects as planned. CARB staff will also report on whether VMT per capita is directionally tracking with reported GHG per capita.

Policy Commitments

For the SCS Determination Element of the Guidelines, CARB staff is proposing a series of five Policy Commitment analyses evaluating whether the policies, strategies, and key actions from the SCS support its stated GHG emission reductions. In addition CARB staff will evaluate whether there are any risks to not achieving the SCS GHG emission reductions. These five Policy Commitment analyses include the following, and are described in more detail below:

1. **Trend Analysis.** Do the data show that the plan is moving a direction consistent with the planned outcomes, including the planned regional GHG reductions?
2. **Elasticity Analysis.** Does the scientific literature support the stated GHG emissions reductions?
3. **Policy Analysis.** Are there supportive key actions for the SCS strategies?
4. **Investment Analysis.** Do the investments support the stated GHG emissions reductions?
5. **Plan Adjustment Analysis.** If the region is falling behind on implementation, what measures are the MPO taking to correct course in the plan, as necessary, to meet the target?

Trend Analysis

The Trend Analysis evaluates whether the data shows the plan is moving in a direction consistent with the planned outcomes, including the planned regional GHG reductions. As part of the current SCS evaluation guidelines, CARB staff quantifies the changes of all MPO-provided performance indicators from base year to GHG emission reduction target years. This information is used to analyze whether the calculated changes of various performance indicators are consistent with the trends of GHG and VMT changes claimed by MPOs. CARB staff will continue to analyze the trends in the performance indicators listed below for directionality that support the stated per capita GHG emission reductions.

Screening Criteria: CARB staff will be checking the directionality of trends in the following performance indicators as measured in 2035 compared with 2005. In the Trend Analysis Screening, all SCS performance indicators listed below should track the direction of the sign noted.

- Household vehicle ownership (-)
- Mode split (non-auto: +, auto: -)
- Travel time by mode (non-auto: -)
- Transit ridership (+)

- Average vehicle trip length (-)[33]
- Seat utilization (+)
- Household VMT/capita (external-external [XX] trips excluded) (-)
- GHG/capita (-)

If an MPO's SCS does not satisfy the trend screening analysis for all applicable indicators, CARB staff will look to the MPO to provide potential explanations.

Elasticity Analysis

The Elasticity Analysis proposed here is new to CARB's determination, and as such will be piloted for the third round of SCS evaluations. The analysis evaluates whether the scientific literature supports the SCS' stated GHG emissions reductions. Currently, MPOs use their travel demand models to quantify potential VMT and GHG changes of the SCS strategies. Modeling outputs are determined by the synergistic effects of strategies, demographic changes, model performance, and other assumptions.
A number of studies report that regional VMT has a quantitative relationship with the implementation of land use, transportation, and other development strategies. These relationships are often referred to as elasticities. CARB staff is developing a standardized elasticity analysis method to evaluate the contribution of strategies and exogenous variables to the total VMT and GHG changes resulting from the SCS as a check on the MPO's reported VMT and GHG results. This analysis will be based on the range of elasticity values reported in existing literature when available, and the MPO's own sensitivity results of its travel demand model. It should be noted that the elasticity analysis is unable to distinguish the contribution of individual projects and does not intend to create any causal relationship between performance indicators and regional VMT; therefore, the relative contribution is calculated by the following concept formula:

$$\%\ \Delta\ \textit{Performance Indicator} = \%\ \Delta\ \textit{Plan Attribute} * \textit{Elasticity} * \textit{Effect size}$$

Defined as:

"% Δ Performance Indicator" refers to the expected quantitative outcome due to the change in the plan attribute.

"% Δ Plan Attribute" refers to the changes in the plan that are known to be directly associated with VMT and GHG;

[33] The average vehicle trip length may go up if MPOs shift the short distance trips to active transportation through SCS strategies.

"Elasticity" is the quantitative relationship between the change in the plan attribute (strategy variable) and the performance indicator (VMT or GHG), which can be obtained from literature, MPO's sensitivity tests[34], and/or other empirical sources; "Effect size" refers to a participation rate; an optional coefficient (e.g., % of population/household/employment in the region) used to scale the impact of a strategy that does not universally apply to the entire region.

For each factor included in the elasticity analysis, CARB staff will: identify the available data for performing the analysis (source, geographic granularity, level of aggregation, etc.); and discuss uncertainties related to potential double-counting, omission of synergistic effects, or other methodological issues inherent in cumulating individual elasticities to estimate a total effect.

After conducting the listed elasticity analyses, CARB staff will estimate the range of contribution of strategies on the regional VMT and GHG emission reductions based on the *aggregated* result. The sum of the aggregated result may be a range, and is not intended to match the total regional GHG emission reductions due to the lack of synergistic effects and other confounding factors such as the spatial location of strategies. This analysis will be used as one component of the overall strategy evaluation and will expand upon the trend analysis described earlier, and serves as a check on whether the scale of the stated GHG emission reductions from the SCS is roughly supported by the literature.

Screening Criteria: CARB staff will apply the following standard in its elasticity analysis. In the Elasticity Analysis Screening, CARB's analysis should show that the aggregated elasticity result (including exogenous variables, strategies and off-model calculations) can account for at least 85 percent of the reported plan performance.

Table below illustrates an example hypothetical Elasticity Analysis. The screening criteria developed for the Elasticity Analysis are meant to serve as a means of identifying potential issues or problems that warrant additional review by CARB staff. In other words, if the model-based result is sufficiently different from the elasticity-based result beyond an error range that CARB staff deems problematic with respect to the State's GHG emission reduction goals, then CARB staff will take additional steps to collect more information and discuss potential explanations with the MPO. It may be

[34] See Appendix B for a detailed discussion of the sensitivity tests using land use and travel demand models requested of MPOs. The results of these sensitivity tests are validated against peer-reviewed literature by CARB staff. If the MPO's model is valid for a given test, the elasticity from the MPO's travel demand model can be used in the calculation for that particular attribute (strategy). If the MPO's model is outside the statistical range provided by the literature, then data from the literature will be the basis for the calculation.

possible that an MPO's strategy is not well-described by the plan attributes used in the screening analysis. In this case, CARB staff may work with the MPO staff to develop substitute attributes that can be used to complete the Elasticity Analysis.

Table 3. Example Elasticity Analysis

Plan Attribute	**% Δ Plan Attribute from 2005-2035[1]**	**Elasticity[2]**	**Effect size**	**% Δ VMT or % Δ GHG**
Net Residential Density	25%	-0.05	100% regional average	-6.12%
Increased Transit Frequency	40%	-0.8	15% regional coverage; 4% mode share	
Transit Capacity Expansion	15%	-0.7	30% regional coverage	
Bike and Pedestrian Infrastructure	30%	-0.04	40% regional coverage	
Toll Rate	20%	-0.3	30% regional coverage	
Roadway Capacity	5%	+0.6	25% new population growth	
Off-Model Strategies (TDM, Electric vehicle network, Telecommute)[3]				-3.50%
Subtotal Contribution from Strategies				-9.62%
Exogenous Variables	**% Δ Plan Attribute from 2005-2035[1]**	**Elasticity[2]**	**Effect size**	**% Δ VMT or % Δ GHG**
Auto Operating Cost	42%	-0.15	100% regional coverage	-9.1%
Household Income	-25%	-0.11	100% regional coverage	
Aggregated Result Grand Total[4]				**-18.7%**
Plan Performance				-19%
Screening Criteria: within no less than 85% of reported plan performance				**√ screening criteria met**

Notes:
[1] Data reported by MPO in required data submittal to CARB
[2] Elasticity expressed in percent change in VMT or GHG due to 1 percent change in plan attribute variable (based on sensitivity tests and literature review).
[3] Calculations of GHG emission reductions from off-model strategies will be independently evaluated by CARB staff.
[4] The total in this example is a simple sum, and does not account for loading order nor the synergistic effects of strategies. In addition, the aggregated grand total is the summation of change in plan attributes for individual strategy multiplied by their respective elasticities.

Policy Analysis

The Policy Analysis evaluates whether the SCS contains supportive key actions for the strategies identified in the SCS. CARB staff will be looking for evidence that there are supportive key actions for the SCS strategies, that the investments support the stated GHG emission reductions, and that the region is making course corrections to the plan if they are falling behind on implementation, as necessary to meet the target. The Policy Analysis will be conducted by CARB staff through independent review of the MPO's SCS, dialogue with MPO staff, and researching relevant planning efforts and key actions.

Transportation Policy

CARB staff will qualitatively evaluate the relationship between the stated GHG emission reductions in the SCS and relevant MPO and local transportation actions. For example, actions such as grant or incentive funds to projects that make better use of their existing transit systems through first/last mile connection (e.g., micro transit, bike share), and subsidizing on-demand dynamic ridesharing support key SCS transportation strategies. On the other hand, not reflecting short- and long-run impacts of capacity and associated induced VMT in the region's travel demand modeling suggests to CARB that the SCS may be at risk of not meetings its GHG emission reduction targets.

Land Use and Housing Policy

CARB staff will qualitatively evaluate the relationship between the SCS and relevant MPO land use and housing activities and actions. For example, actions such as incentivizing transit-oriented development support the SCS's housing strategies. On the other hand, not reflecting approved large development projects or annexed new growth that were not envisioned or analyzed in the prior SCS suggests to CARB that the SCS may be at risk of not meeting its targets unless plan adjustments are made.

Pricing Policy

A number of MPOs have indicated they will be exploring road pricing strategies in the future RTP/SCS. SB 375 provides that when establishing the targets, CARB shall take into account GHG reductions that will be achieved by improved vehicle emission standards, changes in fuel composition, and other CARB measures that will reduce GHG emissions in the affected region (including prospective measures). (Government Code Section 65080(b)(2)(A)(iii)). When CARB updated the SB 375 targets in March 2018, CARB took into account GHG reductions from these CARB measures and also potential future state pricing.[35] State-initiated strategies will complement and support achievement of greater GHG emissions reductions through SB 375. Statewide road user pricing is an example of a potential future State-initiated strategy that an MPO should not use to demonstrate compliance with the SB 375 GHG emission reduction targets. However, the MPO could use its ability to make reasonable assumptions about revenues appropriated to the MPO from State road user pricing that could be re-invested to further the region's SCS. If an MPO were to initiate a specific regional or local pricing strategy (e.g., local/regional tolls or congestion pricing) through action taken by the MPO's Board of Directors or local jurisdictions, then the MPO could take full credit for the VMT and associated GHG emission reductions attributable to that action toward achievement of its SB 375 GHG emission reduction targets.

Vehicle Technology and Enhanced Mobility Policy

We are embarking on a new era of mobility brought about by the emergence of autonomous vehicle technology and connected transportation infrastructure that is likely to yield the greatest transformation to the transportation system since the State Highway System was built, and has the potential to totally transform personal travel over the next 20 years and beyond.

If claiming GHG emission reductions for enhanced mobility strategies[36], CARB expects the MPO to clearly define all data sources, assumptions, and the calculation methodology.

Investment Analysis

The Investment Analysis evaluates whether SCS investments support the region's expected GHG emissions reductions. CARB staff will evaluate and compare the expenditures in this plan and the previous plan, looking for evidence of whether the planned investments support the stated GHG reductions and whether the MPOs are shifting their investment priorities consistent with SCS strategies. For example, if SCS

[35] CARB, Updated Final Staff Report: Proposed Update to the SB 375 Greenhouse Gas Emission Reduction Targets, 2018. Available at https://www.arb.ca.gov/cc/sb375/sb375_target_update_final_staff_report_feb2018.pdf

[36] In response to recent direction from the Governor, CARB is assessing the viability of new regulations to increase zero emission vehicle adoption rates in public and private fleets across the state, including the light-duty fleets owned by transportation network companies that provide on-demand ride-hailing services. For more information about the proposed regulation, please visit https://www.arb.ca.gov/msprog/zero_emission_fleet_letter_080118.pdf. For more information about related legislation, SB 1014, the California Clean Miles Standard and Incentive Program: Zero-Emission Vehicles (Skinner, 2018). Available at:https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB1014.

strategies are focusing on transit and active transportation, CARB staff will look for evidence of investments to fund those strategies. As another example, if SCS strategies rely upon increased density near transit areas, CARB staff will consider whether the MPO uses discretionary funds to foster or incentivize targeted local actions to increase density in the right places.

In addition, CARB staff may compare the region's long-range funding strategy to the region's shorter-term Transportation Improvement Program (TIP) as one source to obtain a better understanding of how the region has been and is planning to prioritize near-term spending. If the types of near-term investments are consistent with the priorities in the RTP/SCS, this will suggest to CARB that investments are being made that support SCS strategies. CARB staff understands that TIP may not reflect all the sources of investments such as state, local or formula funding. However, these plans can give CARB staff an understanding of what projects are in the pipeline and how those may change travel patterns in the future (for example, if a major transit construction project was recently begun, transit ridership would be more likely to increase in coming years).

Plan Adjustment Analysis

The Plan Adjustment Analysis evaluates what measures are being taken, as necessary, to correct course to meet the target if the region is falling behind on implementation of SCS strategies. CARB staff will review SCS implementation using plan attributes and performance indicators of overall GHG emission reduction target achievement. If CARB staff determines that an MPO is not hitting milestones with respect to SCS implementation, to give CARB staff the assurances it needs to determine that a region is capable of meeting its 2035 GHG emission reduction targets, CARB staff will look to the MPO for evidence that the MPO has considered these challenges and has either changed its strategy, or is putting measures in place to accelerate implementation in order to stay on track, if applicable. Some MPOs have indicated that they will provide an RTP/SCS implementation assessment report for this element that describes the implementation status of adopted RTP/SCS strategies.

If the region is falling significantly behind on implementation or not hitting performance benchmarks, and there is insufficient evidence that a course correction is underway, then the SCS may be at risk of not meeting the GHG emission reduction targets.

Incremental Progress

During the 2018 GHG emission reduction target update process, some of the MPOs reported to CARB that, due to changes in factors beyond their control, it will require even greater effort to achieve the same level of per capita GHG emission reductions reported in their current SCSs. This information was shared with CARB as part of the 2018 target update process. According to the MPOs, simply staying on course to achieve the previous SB 375 GHG emission reduction targets established in 2010 will be a stretch of their current resources, let alone achieving the more aggressive targets adopted by the Board in 2018. For example, the Southern California Association of Governments (SCAG) and the Sacramento Area Council of Governments (SACOG) estimated that their currently adopted plans would achieve approximately 3 to 5 percent less today than when they were adopted in 2016 simply due to changes in fleet efficiency, associated auto operating cost, and growth projections.[37] In order to continue to meet their SB 375 GHG emission reduction targets, the MPOs are left to make up their respective gaps through and combination of additional innovation, additional strategies, and/or enhancements to existing strategies that reduce GHG emissions.

Thus, in order to demonstrate to CARB that the MPOs are, in fact, stretching to achieve their GHG emission reduction targets, this reporting section proposes a method to focus more squarely on the efforts to reduce GHG emissions through land use and transportation strategies from one plan to the next.

CARB staff seeks to answer the following questions in this evaluation section:

- What strategies have changed or been added since the last SCS?
- What is the increment of progress achieved through the strategies in *this* SCS as compared to the *last* SCS?

While the incremental progress will not be used for CARB's determination, CARB expects MPOs achieve incremental progress due to its land use and transportation strategy commitments from its second SCS to its third SCS consistent with information shared during the GHG emission reduction target setting process. The results of the analysis will be included in the SCS evaluation report, and shared with the CARB Board.

Figure 2 shows a graphical representation of the exercise that many MPOs already conduct at the outset of their SCS development process to determine whether they project a "gap" or "surplus" with respect to their SB 375 GHG emission reduction target achievement. In fact, some MPOs have discovered that an identical set of strategies

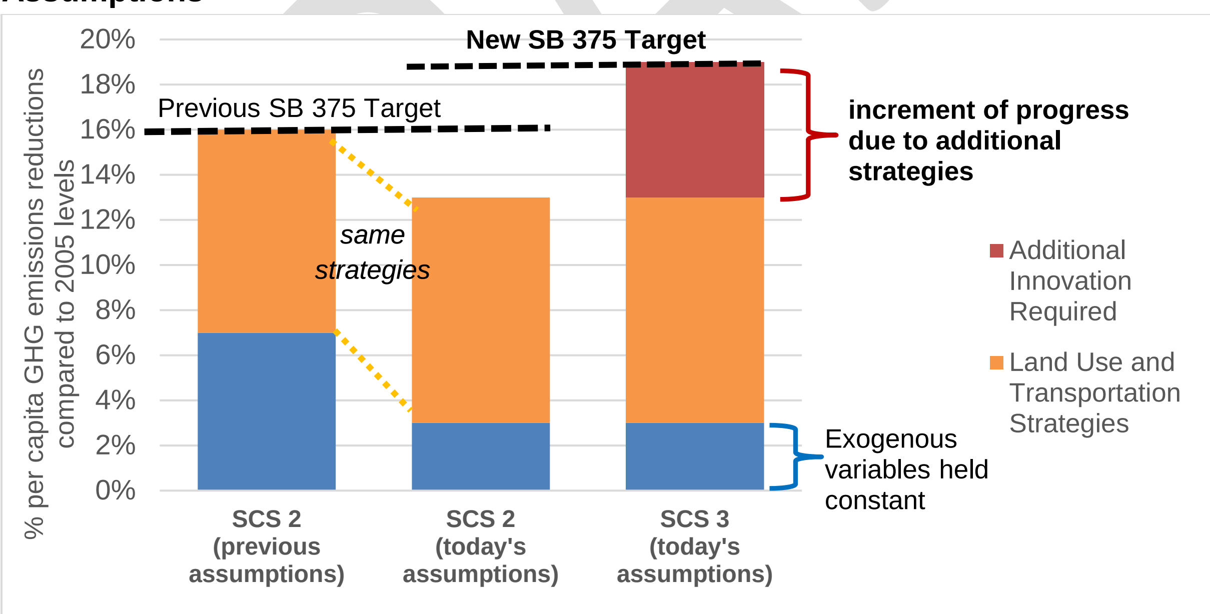
[37] CARB, *Final Staff Report Proposed Update to the SB 375 Greenhouse Gas Emission Reduction Targets: APPENDIX B. MPO Scenario and Data Submittals*. October, 2017. Available at: https://www.arb.ca.gov/cc/sb375/appendix_b_mpo_scenario_and_data_submittals_october_2017.pdf.

achieves less per capita GHG emission reduction simply due to changes in data on fuel price, household income, and fleet efficiency.

For example, if the price of fuel is expected to increase in the future, the MPO would expect to see a reduction in VMT (assuming all other factors stay constant). Household income is also known to influence vehicle ownership and VMT. These factors are sometimes referred to as "exogenous" variables in the travel demand model. As economic conditions change, MPOs must forecast such socioeconomic conditions to reflect the best available information in their travel demand models. Similarly, demographic trends in a region influence how much people drive. These sometimes confounding factors are central determinants of travel behavior, and should be updated as conditions change. However, these factors are outside of the MPOs' control, and have nothing to do with the level of effort represented in the SCS itself.

Figure 2 below also shows graphically an example comparison of the incremental progress between the previous SCS and the updated SCS when controlling for exogenous factors, along with the relationship to the previous SB 375 GHG emission reduction targets and the newly adopted 2018 targets. The values reflected in this figure are a hypothetical representation, and not intended to imply a numeric target.

Figure 2. Example of a Comparison of SCS Performance with Updated Assumptions



For MPOs that choose to voluntarily conduct an increment of progress test, CARB staff proposes MPOs conduct a scenario analysis based on specially prepared input datasets for the current SCS to allow for a normalized comparison, to the greatest degree feasible, to the proposed SCS. In other words, a scenario which represent the previous SCS using today's assumptions about exogenous variables for the region. A list of recommended exogenous variables to normalize can be found below in Table 4. Because the new and updated assumptions about such exogenous variables may be available at the same time as MPOs prepare their Technical Methodology (discussed in Appendix A) under California Government Code § 65080(b)(2)(J)(i) , CARB requests that MPOs submit the results of these analyses at that time. If not available, MPOs should submit this info as part of an updated MPO technical methodology.

Table 4. 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] Cross-walking the relationship of certain variables back to the modeling conducted for the previous 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 previous SCS. CARB staff expects a good-faith effort to construct a reasonable approximation. Exact accounting is not necessary.

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.

During the assessment, CARB will then take the difference of the per capita GHG emissions from the previous plan submitted with the technical methodology, and the newly updated plan to determine the plan-over-plan incremental progress, and whether it's consistent with information shared during the target setting process. In addition, CARB staff will be looking for evidence that there are supportive key actions for incremental progress of SCS strategies both in terms of policy and investment changes. In addition, CARB staff may look at the phasing of investments, when available, as phasing impacts how much cumulative reductions will be achieved by years 2030 and 2050 in support of broader State climate goals.

This approach will highlight the level of effort necessary by an MPO to make up any gap in GHG emission reductions due to changing assumptions beyond its control, which is not well-conveyed through a basic comparison to the per capita GHG emission reduction targets. This evaluation will help communicate whether the 2018 GHG emission reduction targets do require the MPOs to continue to stretch and innovate.

CARB staff recognizes that this approach will not always work for every MPO because of the continuing need to update modeling platforms and shifting datasets. In the instance where an MPO has significantly updated or upgraded its travel demand model or some other component of its modeling has substantially changed in a way that will not allow for the MPO to report an apples-to-apples comparison with the previous SCS, CARB staff will conduct an independent assessment using the following alternative method to assess the Increment of Progress.

In the case where a direct model-to-model comparison is not possible, or if the MPO does not report its increment of progress for any reason, CARB staff will conduct this alternative assessment. The analysis will compare the data submitted by the MPOs for their **land use and transportation attributes** for year 2035 with those obtained from previous data submittals from prior SCSs to determine the incremental progress in those strategies. MPOs that are increasing net regional average density, share of multi-family housing, transit frequency and service, and miles of bike infrastructure would be considered to be making incremental progress on strategies. CARB staff will also compare the **performance indicators** for year 2035 with those obtained from previous data submittals from prior SCSs to verify whether the progress of MPO strategies is translating to VMT and GHG emission reductions across plans.

Equity

CARB recognizes that a healthy place to live and basic mobility are fundamental rights for all California residents and is committed to prioritizing environmental justice and equity. In keeping with this commitment, CARB has included equity as a reporting element of the SCS Guidelines. Currently, the CTC's *2017 Regional Transportation*

Plan Guidelines for Metropolitan Planning Organizations[38] provides guidance for MPOs to conduct their required equity analysis. Addressing equity ensures the programs, policies, and activities associated with regional transportation improvements identified in the RTP/SCS do not have a disproportionately high and adverse impact on low income or minority populations.

The goal of the SCS Guidelines is to report whether MPOs are conducting equity analysis as part of their SCS, as well as the type of qualitative and quantitative equity analyses conducted by MPOs. The following sections describes how CARB staff will begin reporting the equity analysis conducted by MPOs:

- **Identifying vulnerable communities:** Reporting how MPOs identified vulnerable communities within their jurisdiction.
- **Measurement of Impact:** Documenting the metrics and performance measures identified by MPOs to determine (under Title VI) whether transportation and land use changes identified in the RTP result in disparate impacts to minority communities and populations and (with respect to EJ) to identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of programs, policies, and activities on low-income populations and minority populations resulting from the transportation and land use changes in the RTP .
- **Equity Analysis:** Reporting the quantitative and qualitative equity analysis conducted by MPOs that includes an analysis of impacts that identifies any disparate impacts on the basis of race, color, or national origin (Title VI) and identifies and addresses, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations.
- **Public Outreach:** Documenting the stakeholder engagement process established by MPOs for public outreach and engagement with vulnerable communities.

[38] California Transportation Commission. 2017. *2017 Regional Transportation Plan Guidelines for Metropolitan Planning Organizations*.
http://www.dot.ca.gov/hq/tpp/offices/orip/rtp/docs/2017RTPGuidelinesforMPOs.pdf.

VII. Overall SCS Prgram Evaluation

Staff proposes to modify the scope of the elements it considers when determining whether to accept or reject the MPO's determination that an SCS would achieve the assigned regional passenger vehicle GHG emission reduction targets, if implemented, per Government Code § 65080 (b)(2)(I)(ii). Historically, this determination has primarily relied on use of travel demand and emissions modeling output provided by the MPO. This quantitative determination prepared by the MPO will still be relied upon as a check of whether the SB 375 GHG emission reduction targets would be met, but the additional elements that assess whether there are supportive key actions[39] for the SCS strategies[40], including investments, and whether the region is making plan adjustments, as necessary to meet the target, to account for changing conditions, including potential risks to achieving its land use and transportation goals. In other words, the outcomes of the following five Policy Commitment analyses will give CARB staff the confidence to accept an MPO's determination that an SCS meets the applicable per capita GHG emission reduction targets:

1) **Trend Analysis:** Do the data show that the plan is moving a direction consistent with the planned outcomes, including the planned regional GHG reductions?
2) **Elasticity Analysis:** Does the scientific literature support the stated GHG emissions reductions?
3) **Policy Analysis:** Are there supportive key actions for the SCS strategies?
4) **Investment Analysis:** Do the investments support the stated GHG emissions reductions?
5) **Plan Adjustment Analysis:** If the region is falling behind on implementation, what measures are the MPO taking to correct course in the plan?

Further, CARB's Strategy-based SCS Program and Evaluation will also report three additional elements including Tracking Implementation (SB 150 Reporting), Incremental Progress, and Equity. However, these elements will not be used for CARB's determination.

If any **Policy Commitment** analysis screening criteria are not met, CARB staff will look to the MPO to provide supporting information to explain the outcome. If there is insufficient evidence to explain or overcome a deficiency in any of the assessments, this could be grounds for CARB staff to reject an MPO's determination.

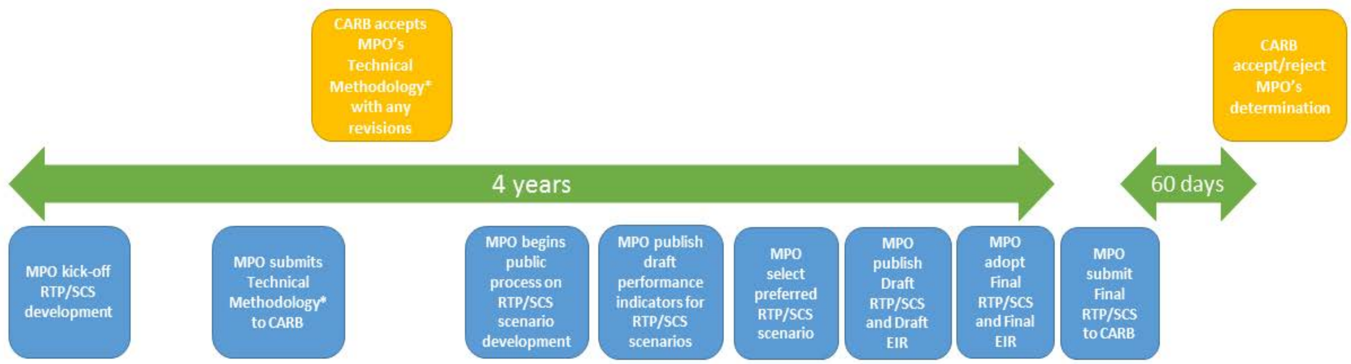
[39] as the specific activities that support or ensure successful implementation of the strategies
[40] as the land use and transportation goals and policies of the SCS

VIII. MPO-CARB Information Exchange and MPO Submittal Elements

Summary of Collaboration Milestones between CARB and MPO staff

CARB staff and MPO staff have developed a strong practice of collaboration over the last ten years in support of SCS evaluations under SB 375. CARB staff appreciates the longstanding commitment of staff resources that MPOs have allocated to working with CARB on SCS evaluations. As an MPO develops its RTP/SCS, an information exchange between CARB and the MPO exists throughout the process. It begins early with the submittal of the Technical Methodology and ends with the submittal of a region's adopted SCS and accompanying CARB data request. Figure 3 below shows a conceptual diagram of the collaboration milestones between the MPO and CARB throughout the RTP/SCS development and approval process.

Figure 3. Process Diagram for MPO and CARB Collaboration Milestones



* The MPO is required under Government Code § 65080(b)(2)(J)(i) to submit a Technical Methodology that it intends to use to estimate GHG emissions from its SCS to CARB prior to starting the public participation process adopted pursuant to Government Code § 65080(b)(2)(F).

Technical Methodology to Quantify GHG Emissions

The MPO is required under Government Code § 65080(b)(2)(J)(i) to submit a Technical Methodology that it intends to use to estimate GHG emissions from its SCS to CARB prior to starting the public participation process adopted pursuant to Government Code § 65080(b)(2)(F).

> *Prior to starting the public participation process adopted pursuant to subparagraph (F), the metropolitan planning organization shall submit a description to the state board of the technical methodology it intends to use to estimate the greenhouse gas emissions from its sustainable communities strategy and, if appropriate, its alternative planning strategy. The state board*

shall respond to the metropolitan planning organization in a timely manner with written comments about the technical methodology, including specifically describing any aspects of that methodology it concludes will not yield accurate estimates of greenhouse gas emissions, and suggested remedies. The metropolitan planning organization is encouraged to work with the state board until the state board concludes that the technical methodology operates accurately.

The submission of the Technical Methodology occurs after the MPO has developed the overall framework for its SCS and includes a description of the methodology the MPO intends to use to estimate the GHG emissions from its SCS. Upon receipt of the Technical Methodology, CARB responds to the MPO with written comments about the Technical Methodology, including specifically describing any aspects of that methodology it concludes will not yield accurate estimates of GHG emissions, and suggested remedies. A checklist including an example of what information and data should be included in a Technical Methodology can be found in Appendix A.

Submittal of Final RTP/SCS to CARB

Once the Final RTP/SCS is adopted by the MPO governing Board, the MPO submits its adopted Final RTP/SCS to CARB. CARB will publish its evaluation within 60 business days of receipt of the final plan, including all supporting data needed to complete staff's evaluation.

Summary of MPO Data Submittal Elements

- Land use allocation tabulated by place type
- Transportation project list tabulated in Excel (including project type, cost, funding source (if known), project time period [e.g., base year through 2020, 2020 through 2035, or beyond 2035], and location)
- MPO data submittal to CARB (below)
- Off-model documentation and calculations (if applicable)
- EMFAC input and output files
- Model sensitivity test results
- Model validation document
- Any other information to support GHG quantification (if applicable)

MPO Data Submittal to CARB						
Modeling Parameters	**2005**	**Base Year**	**2020**	**2035**	**Plan Horizon Year**	**Data Source**
Socioeconomic and Demographic Data						
Modeled Population[1]						Model input
Vehicle Operating Costs ($/mile)						Model input
Average Toll Price ($/mile)						Model input
Average median Household Income ($/year)						Model input
Total Number of Households						Model input
Total Number of Jobs						Model input
Land Use Data						
Total Developed Acres						Model input/GIS
Total Housing Units						Model input
Total Single-Family Housing Units (du)						Model input
Share of Single-Family Housing Units (%)						Calculated: (Total single-family units/total housing units)
Total Multi-Family Housing Units (du)						Model input
Share of Multi-Family Housing Units (%)						Calculated: (Total multi-family units/total housing units
Net Residential Density (dwelling units/acre)						
Regional Total						Model input
Place Type 1						Model input
Place Type 2						Model input
Place Type 3						Model input
Place Type 4						Model input
Total Housing Units Within ½ Mile of a High-Quality Transit Station						Model input/GIS

MPO Data Submittal to CARB						
Modeling Parameters	**2005**	**Base Year**	**2020**	**2035**	**Plan Horizon Year**	**Data Source**
Total Jobs Within ½ Mile of a High-Quality Transit Station						Model input/GIS
Transportation Network Data						
Freeway and General Purpose Lanes - Mixed Flow, auxiliary, etc. (lane miles)						Model input
Freeway Tolled Lanes (lane miles)						Model input
Freeway HOV Lanes (lane miles)						Model input
Arterial/Expressway (lane miles)						Model input
Collector (lane miles)						Model input
Average Transit Headway (minutes)						Model input
Total Transit Operation Miles						Model input
Transit Total Daily Vehicle Service Hours						Model input
Bike and Pedestrian Lane (class I, II, & IV) Miles						Model input
Plan Performance Indicators						
Household Vehicle Ownership						Model output
Average Trip Length (miles/day)						Model output
Drive Alone						Model output
Shared Ride						Model output
Public Transit						Model output
Bike & Walk						Model output
Average Travel Time by Trip Purpose (minutes)						

MPO Data Submittal to CARB						
Modeling Parameters	**2005**	**Base Year**	**2020**	**2035**	**Plan Horizon Year**	**Data Source**
Commute Trip						Model output
Non-Commute Trip						Model output
Average Travel Time by Mode (minutes)						
Drive Alone						Model output
Drive Alone (TNC)						Model output
Shared Ride						Model output
Shared Ride (pooled TNC)						Model output
Public Transit						Model output
Bike						Model output
Walk						Model output
Average Travel Time for Low-Income Populations (minutes)						Model output
Mode Share (%)						
Drive Alone						Model output
Drive Alone (TNC)						Model input
Shared Ride						Model output
Shared Ride (pooled TNC)						Model input
Public Transit						Model output
Bike						Model output
Walk						Model output
Seat Utilization						Model output
Transit Ridership (Average daily boardings)						Model output
Total VMT per weekday (all vehicle class) (miles)						Model output
Total VMT per weekday for passenger vehicles (CARB vehicle classes						Model output

MPO Data Submittal to CARB						
Modeling Parameters	**2005**	**Base Year**	**2020**	**2035**	**Plan Horizon Year**	**Data Source**
LDA, LDT1, LDT2, and MDV)						
Total II VMT per weekday for passenger vehicles (miles)						Model output
Total IX/XI VMT per weekday for passenger vehicles (miles)						Model output
Total XX VMT per weekday for passenger vehicles (miles)						Model output
SB 375 VMT per capita						Calculated: (II + IX/XI passenger VMT) / population
GHG Emissions Data						
Total CO_2 emissions per weekday (all vehicle class) (tons/day)						EMFAC model output
Total SB375 CO_2 emissions per weekday for passenger vehicles (CARB vehicle classes LDA, LDT1, LDT2, and MDV) (tons/day)						EMFAC model output
Total II CO_2 emissions per weekday for passenger vehicles (tons/day)						EMFAC model output
Total IX/XI CO_2 emissions per weekday for passenger vehicles (tons/day)						EMFAC model output
Total XX CO_2 emissions per weekday for passenger vehicles (tons/day)						EMFAC model output

MPO Data Submittal to CARB						
Modeling Parameters	**2005**	**Base Year**	**2020**	**2035**	**Plan Horizon Year**	**Data Source**
SB 375 CO_2 per capita (lb/day)						Calculated: (II + IX/XI CO_2) / population / 2000 lb/ton
EMFAC Adjustment Factor (if applicable)	n/a	n/a			n/a	CARB Methodology for Estimating CO_2 Adjustment
Off-Model CO_2 Emissions Reductions (%)						
Strategy 1	n/a	n/a				MPO estimated
Strategy 2	n/a	n/a				MPO estimated
Strategy 3	n/a	n/a				MPO estimated
Strategy 4	n/a	n/a				MPO estimated
Strategy 5	n/a	n/a				MPO estimated

Appendix A: Additional Details for Technical Methodology Submission

This section proposes a standardized template for MPOs submitting their Technical Methodology to estimate GHG emissions for their SCS to CARB under Government Code § 65080(b)(2)(J)(i). This template was developed from previous Technical Methodology submissions, and reflects the new direction adopted by CARB through the 2018 GHG emission reduction target update process. The intention of the template is to serve as a guide for MPOs and help improve consistency among MPOs and minimize the need for revisions for CARB to accept the proposed MPO's method.

Cover Letter

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

Technical Methodology

The Technical Methodology aggregates several steps an MPO follows to estimate GHG emission reductions from its SCS. CARB staff recommends MPOs include the following content in their submission to CARB

Title

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

Introduction

- Purpose of Technical Methodology reference to Government Code § 65080(b)(2)(J)(i)
- Applicable per capita GHG emission reduction targets set by CARB
- Overview of analysis years including year and purpose of modeling that specific year
- 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 SCS schedule, including start date of public process for MPO scenario development.
- Significant or notable changes in regional planning context since the prior SCS was adopted.

Overview of Existing Conditions

- Notable changes to existing regional or local planning contexts that are likely to influence the SCS development process (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]).
- 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 (population, jobs, housing) compared to last SCS.
- Explanation of any change 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 SCS strategies under consideration, to the extent known and available. Table 5 provides examples of quantification approaches associated with potential SCS strategies

Table 5. Example SCS Strategy Quantification Approaches

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., EMFAC 2017)

Land Use/Travel Demand Modeling

- Description of 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 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-run effects of induced demand for new roadway capacity projects.

List of Exogenous Variables and Assumptions for Use in Proposed SCS

- At this time, the MPO should lockdown its assumptions, to the extent known and available, for independent (exogenous) variables (as shown in Table 6) that are inputs to its travel demand modeling that are not part of the SCS scenario development process, and document those variables in this submittal.

Table 6. 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] Cross-walking the relationship of certain variables back to the modeling conducted for the previous 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 previous SCS. CARB staff expects a good-faith effort to construct a reasonable approximation. Exact accounting is not necessary.

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.

- Assumptions 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).

Per Capita GHG Emissions from Prior SCS

- Using the assumed values listed above for exogenous variables for use in the SCS under development, the MPO should conduct travel demand modeling for the previous SCS using these input variables. This result will be used as the basis for comparison in the "Increment of Progress Test" during CARB staff's subsequent SCS evaluation.

Off-Model Strategies

- List all off-model strategies under consideration that may be used in the SCS including proposed emissions calculation methods and assumptions (See Appendix E).[41]
- Specify how the MPO will develop assumptions about an off-model strategy's 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 on off-model strategy performance to date, adopted investment commitments, and project outcomes (e.g., existing program utilization).

Other Data Collection Efforts

- These might include but are not limited to data collected from regional surveys on travel behavior, compiled project information from local jurisdictions, census data, and/or traffic counts.

Note on the Technical Methodology

CARB understands that the MPOs are Board-driven agencies and RTP/SCS scenarios are developed with input from a robust public process. It is understood that upon submission of the Technical Methodology, CARB will receive the level of detail available

[41] 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 strategy in all future SCSs. If the MPO is no longer implementing the off-model strategy, the MPO should document its termination of that strategy in the Technical Methodology submittal. If the off-model strategy is now reflected in the travel demand modeling due to model upgrade or improved model sensitivity, the MPO should document that it 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.

at time of submission with more detail forthcoming as it is developed through the SCS process. CARB staff will continue to work closely with the MPOs as preferred scenarios and assumptions are developed.

Appendix B: Additional Details for Model Sensitivity Tests

This section provides additional details regarding the information CARB staff collects from MPOs to support its technical review process. As stated previously, if the MPO's validate and calibrate their 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, and this section provides additional detail of 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 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 SCS strategies not captured in travel demand modeling.

Sensitivity Tests

CARB staff requests MPOs to conduct travel demand model sensitivity testing in support of the strategy-based program evaluation of the SCS for two reasons:

1) To examine the responsiveness of the travel demand model to 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 strategy-related model input variable at a time (e.g., transit frequency, auto operating cost, land use density) 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 stated SCS strategies. If independent data are available, CARB checks to determine whether MPO's sensitivity test results are within the range of values published in relevant empirical literature. This is done by identifying the appropriate empirical literature for comparison with the results of the MPO sensitivity tests and then applying the elasticities found in the empirical studies to the changes in the MPO's sensitivity tests outcome. In cases where the test results fall outside of the expected range and/or go in different directions, MPO staff need to provide a clear explanation and supporting evidence, such as survey data, planning assumptions, modeling parameters, structure, and formulations, or other factors that could possibly explain the response of the model to the tested strategy.

An MPO only needs to conduct the applicable model sensitivity tests for its particular SCS strategies that are understood to be represented within the travel demand model. If the MPO's model documentation clearly indicates that a 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 need not conduct the respective sensitivity test. In addition, if an MPO previously conducted a sensitivity test for a given strategy in support of CARB's evaluation of its prior SCS, and no changes to the travel demand model have occurred since the last SCS was adopted, then the MPO may note this conclusion, and need not repeat the respective test. Finally, if an MPO does not propose a given strategy as part of its SCS, 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, and preparation and documentation of sensitivity tests by MPO technical staff. The following is the general process of conducting sensitivity tests and the roles and responsibilities of the MPO and CARB:

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

Step 1: CARB staff works with the MPO staff to develop a list of sensitivity tests that represent key SCS strategies (e.g., increased density, improved transit service). The desired inputs and outputs are listed below by the type of SCS strategy. CARB and MPO staff also establish 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 upon needs. MPO staff can either submit test results to CARB staff by completion of each test (preferred), or at the completion of all sensitivity tests.

Step 3: CARB staff identifies the appropriate empirical literature for comparison with the results of the MPO sensitivity tests. Staff recommends starting with the list of studies reviewed under contract with University of California: www.arb.ca.gov/cc/sb375/policies/policies.htm. CARB staff conduct sensitivity 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 studies to the input changes in the MPO's sensitivity tests. The result is an expected range of outputs based on the 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 if the sensitivity test outputs move in a direction consistent with the literature. Staff then goes one step further to determine if the amount of change is appropriate, that is do 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: When initial analyses of the sensitivity test results are completed, CARB staff will share findings and 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 final assessment of the model sensitivity to key SCS strategies.

Discussed below are different categories of sensitivity tests that CARB typically requests from MPOs based on the strategies employed.

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

If a given strategy is not represented by one of the listed sensitivity tests, CARB staff can give guidance to MPO staff on selecting the model variables that are related to the applicable strategy, and the outputs that can be used to develop performance indicators.

Land Use-Related Sensitivity Tests

Land Use-Related Sensitivity Tests evaluate land use related strategies that reduce VMT and GHG emissions in planning areas through methods such as, but not limited to, infill development, compact development, increase in density, proximity to transit. Common variables CARB may recommend to MPOs for inclusion in their Land Use-Related Sensitivity Tests are based upon the specific SCS strategies under evaluation: regional accessibility, mix of use, proximity to transit, street pattern, residential density, job/housing balance, etc. Table 7 summarizes each Land Use-Related Sensitivity Test, recommended variation in test variable (scenarios), and corresponding inputs and outputs.

Table 7. Land Use Sensitivity Tests and Reporting

Sensitivity Test	Model Input(s)	Scenario(s)	Output(s)[42]
Regional Accessibility	Transportation network density	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by purpose • Mode share • Transit ridership • VMT
Mix of Use	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	No. of household around 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 region wide or in interested area(s) of the region	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 that MPOs use any of the two approaches below to when conducting their sensitivity tests on land use variables:

Controlled Variable Approach

The controlled variable approach is simply a hypothesis testing that while all else remain constant, neglecting the supply-demand interaction between inter-dependent variables in reality, what would be the change in model outputs (e.g., VMT, VHT, vehicle

[42] Request model outputs are generally at regional level, however, upon 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.

trips, mode share) with respect to the change in a single land use related variable (e.g., residential density, employment density, compact housing development). MPO needs to keep regional totals for employment, household and population unchanged, but change the composition and/or special allocation of these elements.

Cross-sectional Analysis

In reality, when changing any of the demographic factor, other factors might be affected. For example, increasing residential or employment density means adding population for jobs to a given area. Such a change can affect the mix of use and regional accessibility, obscuring the particular relationships being researched. To capture this effect while testing the model's sensitivity to land use variables, MPOs can consider using the cross-sectional analysis approach, which uses 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, last-mile connections, and complete streets. Common variables CARB may recommend to MPOs for inclusion in their Transit Infrastructure and Active Transportation-Related Sensitivity Tests are based upon the specific SCS strategeies under evaluation: transit frequency, transition expansion and/or extension, active transportation facilities, and bikeshare facilities. Table 8 summarizes each Transit Infrastructure and Active Transportation-Related Sensitivity Test, recommended variation in test variable (scenarios), and corresponding inputs and outputs.

Table 8. Transit and Active Transportation Sensitivity Tests and Reporting

Sensitivity Test	Model Input	Scenario(s)	Output(s)[43]
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[44]	Walk/bike lane miles	Increase 25%, 50% Decrease 25%, 50%	• Vehicle trips by purpose • Mode share • Transit ridership • VMT
Bikeshare Facility	Mode share of bike trips[45]	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 their Local/Regional Pricing Related Sensitivity Tests are based upon the specific SCS strategies under evaluation: roadway pricing, transit fare cost, and cost of parking. Table 9 summarizes each Local/Regional Pricing-Related Sensitivity Test, recommended variation in test variable (scenarios), and corresponding inputs and outputs.

[43] Requested model outputs are generally at regional level, however, upon 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.
[44] 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.
[45] This input can be the foreseeable increase in bike trips due to improved/new bikeshare programs from the SCS.

Table 9. Sensitivity Tests on Pricing Variables and Reporting

Sensitivity Test	Model Input	Scenario(s)	Output(s)[46]
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

Vehicle Technology and Innovative Mobility Related Sensitivity Tests

Vehicle Technology and Innovative Mobility Related Sensitivity Tests evaluate vehicle technology and innovative mobility-related strategies that can potentially reduce VMT and GHG emissions through methods such as, but notlimited to, increasing access to the regional electric vehicle charging network, promoting dynamic ride-hailing and ridesharing, and traffic smoothing and optimization programs. Since there are limited studies evaluating the impact to VMT and GHG emission reductions from vehicle technology and innovative mobility-related strategies, and the current practice of the quantification of the GHG benefit is generally conducted through off-model analysis. The examples of Vehicle Technology and Innovative Mobility Related sensitivity tests presented in Table 7 are based on related modeling variables to reflect these strategies.

[46] Request model outputs are generally at regional level, however, upon 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 Vehicle Technology and Innovative Mobility Variables and Reporting

Sensitivity Test	Model Input	Scenario(s)	Output(s)[47]
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 its assigned GHG emission reduction target. MPOs should conduct sensitivity test on some of the most common exogeneous variables in their 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)[48]
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 attribute depending on the interested aspect of demographic to test	Various, upon discussion with MPO staff	• Vehicle trips by mode • Mode share • VMT

[47] Request model outputs are generally at regional level, however, upon 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.
[48] Requested model outputs are generally at regional level, however, upon 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.

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. In other words, the outcome of this evaluation method will tell CARB staff whether the model is capable of reflecting the benefits of SCS strategies. Where MPO models are not appropriately sensitive to strategy variables, then MPOs can consider using off-model quantification methods to reflect the benefits of their stated SCS strategies, as discussed in the following section.

CARB staff recognizes that California’s 18 MPOs represent a wide variety of land use types, transportation systems, population centers, and existing development. 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 within their data, but it may not be comparable across MPOs.

Appendix C: Plan Data and Performance Indicators for Strategy Evaluation

This section provides definitions and examples for calculating plan data and performance indicators needed by CARB in an MPO 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 rights-of-way and public facilities).

Transportation Network Data

- **High-Quality Transit:** Fixed route bus or rail service with service intervals no longer than 15 minutes during peak commute hours.
- **Roadway Lane Miles by functional classification:** The total number of roadway lanes by facility type in the region, measured in miles. MPO 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 total mileage of bus service and passenger rail track within the region, measured in miles.
- **Transit Daily Vehicle Service Hours:** The annual vehicle hours of operation of the public transit system in the region.
- **Bike and Pedestrian Lane Miles:** The total number of class I, II, and IV bicycle path facility miles in the region. The MPO may also include miles of pedestrian pathway, if known.

Plan Performance Indicators

- **Household vehicle ownership:** The average number of light-duty vehicles registered (i.e., LDA, LDT1, LDT2, and MDV vehicle categories) per household.
- **Average Trip Length:** The regional average daily trip distance (miles/day) by mode 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 mode, and for low-income populations, calculated using the MPO's travel demand model.

- **Mode Share:** The percentage of average daily trips by travel mode.
- **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 linked or unlinked average daily transit passenger trip boardings, 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.
- **Carbon Dioxide Emissions:** The average daily (weekday) CO_2 emissions reported in tons per day calculated using the VMT output from the MPO's travel demand model.

Appendix D: Guidance on Technical Issues

EMFAC Adjustment Methodology

As part of the SCS development process, MPOs need to provide the estimated CO_2 emission reductions from their proposed plan. Currently, MPOs use the CARB EMission FACtor Model (EMFAC) to estimate passenger vehicle CO_2 emissions by providing VMT and speed profiles for the respective regions from their travel demand models. 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. However, these changes have been observed to influence an MPO's estimate of CO_2 emissions from its SCS.

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 can change the performance of an MPOs SCS even if nothing else changes in their plan. Therefore, in order to normalize the effects from updated versions of EMFAC, CARB staff developed an EMFAC Adjustment Methodology. This methodology is outlined in *Methodology to Calculate CO_2 Adjustment to EMFAC Output for SB 375 Target Demonstrations* (Appendix F), and has been used by MPOs in their previous RTP/SCSs. MPOs should continue to use this approach for their next SCS. In other words, MPOs should use the exact same methodology and version of EMFAC as they did in their second SCS for their third. Effectively, this ensures that should nothing else change, the performance of the third SCS will be identical to the second SCS.

MPOs should use the exact same methodology and version of EMFAC as they did in their second SCS for their third.

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 two rounds of SCS review for every MPO in the State. Some MPOs have requested to update or recalibrate their 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 new evaluation framework, 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 SCS should round to the nearest integer percent, but only after all modeled and off-model GHG calculations have been summed up. In other words, rounding to the nearest integer should only occur at the last step of the MPO's calculation of whether the SCS meets its assigned GHG emission reduction targets. Here is an example to illustrate this method, an MPO has an assigned GHG emission reduction target of -19% in 2035. 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. 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 indicate 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[49].

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

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[49] Small, K.A., K.M. Hymel (2015). The Rebound Effect from Fuel Efficiency Standards: Measurement and Projection to 2035. Prepared for USEPA. EPA-420-R-15-012.

travel behavior and VMT. In the short-run, people change travel behavior by making fewer vehicle trips through trip-chaining[50] 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). According to Hymel, Small, and Van Dender[51] (2010), a 10% increase in fuel price can reduce vehicle travel by 0.26% and 1.31% in the short-run and long-run respectively. However, elasticities may vary by context, and this 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 their plan, while others varied the AOC over time. There were also instances where MPOs only accounted for the cost of gasoline 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. Low Carbon Fuel Standard) 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 the California Air Resources Board's Internet site at: https://ww2.arb.ca.gov/resources/documents/scs-evaluation-resources. The purpose of this the AOC Calculator tool is to bring consistency across 18 MPOs in the approach and variables used to estimate AOC and forecasting fuel price and non-fuel related costs. Further, this will bring uniformity in estimating fuel economy across MPOs both in base and future years. In the future, CARB's AOC 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,

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[50] A trip chaining 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 (https://nhts.ornl.gov/2001/pub/TripChaining.pdf).
[51] Hymel, K. M., K. A. Small & K. Van Dender (2010). Induced Demand and Rebound Effects in Road Transport. Transportation Research Part B, 44(10), 1220-1241.

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, however it 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 ($/Gasoline Gallon Equivalent)

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

MRT_i = Maintenance, Repair, and Tires (MRT) costs of specific fuel type i obtained from the American Automobile Association (AAA)[52] (Cents/Mile)

The number 100 is a conversion factor that converts dollars to cents

VMT_i = VMT by vehicles using fuel i

VMT = Total light duty vehicle VMT in the region

Input Data Sources

In this tool, the default fuel price is based on the CEC Transportation Energy Demand Forecast[53], non-fuel costs are based on information available from the American Automobile Association (AAA)[54], and fuel economy is based on EMFAC2017[55]. 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.

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[52] American Automobile Association 2017. Your Driving Cost: How much are you really paying to drive?, http://exchange.aaa.com/wp-content/uploads/2017/08/17-0013_Your-Driving-Costs-Brochure-2017-FNL-CX-1.pdf
[53] Bahrenian, Aniss, Jesse Gage, Sudhakar Konala, Bob McBride, Mark Palmere, Charles Smith, and Ysbrand van der Werf. 2018. Revised Transportation Energy Demand Forecast, 2018-2030. California Energy Commission. Publication Number: CEC-200-2018-003.
[54] ibid
[55] EMFAC2017, https://www.arb.ca.gov/msei/categories.htm#onroad_motor_vehicles

Fuel Price

CEC provided CARB their 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, or an increase of 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 2000-2017 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 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)

CEC Historical and Projected Fuel Prices, dollar per GGE[56], $2017 (% increase from 2016)				
Calendar Year	**California All Grades All Formulations Retail Gasoline Prices***	**California No 2 Diesel Ultra Low Sulfur Retail Prices***	**Hydrogen***	**Electricity***
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%)

* CEC prices are presented in 2017 dollars, with 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[57] 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

[56] GGE for Diesel (gallon) - 1.155; Electricity (kWh) - 0.031; Hydrogen (kg) -1.019.
[57] The analysis using the Vision Scenario Modeling System used Vision 2.1 updated to reflect fleet characteristics consistent with EMFAC2017.

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:

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

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), small SUVs, medium SUVs, minivans, half ton pickups, hybrid vehicles, and electric vehicles (see Table 10). 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 dollars) were held constant for post-2017 years, as adjustments for future economy are not available. For historical years, AAA maintenance costs were 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[58]:

- 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 10. 2017 Vehicle Maintenance Costs (Cents per Mile)

AAA Vehicle Category[59]	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]			LDT1	LDT2[1]		MDV	Hybrid Vehicle	Electric Vehicle
Maintenance Cost	7.74			8.09	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.									

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.

[58] 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.

[59] American Automobile Association. *Your driving cost How much are you really paying to drive?* (2007 Edition). Available at: https://exchange.aaa.com/wp-content/uploads/2017/08/17-0013_Your-Driving-Costs-Brochure-2017-FNL-CX-1.pdf

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

MPO	VMT				Percent of Total			
	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%
COFCG	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	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%
SCRTPA	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 13 and VMT percentage by LDV class (LDA, LDT1, LDT2, and MDV) data from Table 12, a composite LDV maintenance cost is calculated for each MPO (Table 15). 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 presents maintenance costs by MPO (cents per mile) for calendar year 2017. The vehicle classes summarized in Table 12 include LDV class (LDA, LDT1, LDT2, and MDV) weighted by VMT, hybrid vehicles, and electric vehicles.

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
COFCG	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	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
SCRTPA	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 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 not type in the MPO name nor Calendar year. The MPO drop-down list includes all 18 MPOs, and the Calendar Year drop-down list 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 alternative fuel price using the custom mode by selecting "Custom" from the drop-down list in the "Data Source" column and then entering in 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 American Automobile Association 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 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 equivlent)	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		
	Data Source	Value: Default	Value: Custom	Data Source	Value: Default	Value: Custom	Data Source	Value: Default	Value: Custom	Data Source	Value: Default	Value: Custom	Data Source	Value: Default	Value: 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) to

convert from 2015 dollars to 2017 dollars. An adjustment factor of 1.0169 (1.69%) 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 14[60].

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 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 their 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

[60] American Automobile Association. *Your driving cost How much are you really paying to drive?* (2007 Edition). Available at: https://exchange.aaa.com/wp-content/uploads/2017/08/17-0013_Your-Driving-Costs-Brochure-2017-FNL-CX-1.pdf

region.[61] 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 their 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 evaluations.

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.

[61] 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

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

As MPOs have developed their SCSs, they realized the inherent limitations in their travel demand models and the need for quantifying GHG emission reductions from some SCS strategies, known as off-model strategies[62], outside of travel demand models. The methods to estimate GHG emission reductions from these off-model 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 review 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 reviews of over 20 SCSs, many of which include off-model strategies proposed by MPOs. In conducting these SCS reviews, 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 review of SCSs, as well as from researching the current state of practice, CARB is providing MPOs detailed guidance for the quantification of off-model strategies. Specifically, the purpose and goals of the off-model guidance is to:

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[62] 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[63].

CARB staff anticipates the off-model guidance will improve efficiency and defensibility of the documentation needed for the calculation of GHG emission reduction benefits of off-model strategies. The 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 review process.

Off-Model Evaluation Framework

Based on the purpose and goals indicated above, CARB has prepared an off-model evaluation framework that consists of five elements 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; and
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.

Table 13 below describes the five elements that comprise the off-model evaluation framework in further detail. The off-model evaluation framework provides MPOs with

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

the potential variables and methodologies MPOs should consider when developing and quantifying off-model strategies that is consistent with CARB's SCS review process.

How does CARB use this data?

As part of CARB's SCS review, CARB staff will evaluate an MPO's responses to each of the five elements 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, durable 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* element 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 Climate Change Scoping Plan prepared pursuant to AB 32 and SB 32. In other words, 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 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. Off-Model Strategy Evaluation Framework

Off-Model Strategy Element	Description of Off-Model Strategy Element

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 Element	Description of Off-Model Strategy Element
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* element are general questions MPOs should address and answer in their SCS and in their 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 review, CARB staff will evaluate an MPO's responses to the *Trip and Emissions Data Needs* questions to assist with the 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 element 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. These sample quantification methods are available for use by MPOs at their option, but adhering to these methods 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 its methodology, assumptions, and datasets, in addition to demonstrating how each element 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, it is CARB staff's expectation that an MPO 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.

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. Examples of Transit Improvement Projects

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 street • 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 H-W 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[64] from CARB *Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions: Policy Brief*[65] document.

Step 3: Estimate Mode Shift Factor for shift in trips from private automobile trips to transit[66, 67]

[64] Susan Handy, Kristin Lovejoy, Marlon Boarnet, Steve Spears. *Impacts of Transit Service Strategies On Passenger Vehicle Use and Greenhouse Gas Emissions.* Available at: https://www.arb.ca.gov/cc/sb375/policies/transitservice/transit_brief.pdf. October, 2013
[65] The data presented in the CARB 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.
[66] 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.
[67] American Public Transportation Association. APTA Standards Development Program Recommended Practice. *Quantifying Greenhouse Gas Emissions from Transit*. APTA SUDS-CC-RP-001-09. August 14, 2009.

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*[68,69] 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.

Table 15. Transit Alternative Modes of Travel Choices[70]

Service Area Type and Populatio	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

[68] Ibid.
[69] The data presented in the APTA study includes studies evaluating urbanized and metro areas, including land-use effects caused by transit.
[70] Indicates the percentage of trips by mode that would have been taken if transit service is not available.

Step 4: Estimate Land-Use Multiplier[71, 72].

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[73].

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

a) Preferred Approach: Use region-specific travel demand model AVO assumptions.
b) Alternate Approach 1: Use region-specific survey data.
c) Alternate Approach 2: Use statewide 24-hour average value of 1.5[74].

Step 6: Estimate average regional home-work (H-W) 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[75].

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.

$$VMT_{Dsp} = Ridership_{Base} * Ridership_{Inc} * MSF * \frac{\mathrm{LU}}{AVO} * \mathrm{TL}$$

VMT_{Dsp} = Calculated displaced VMT (miles)
$Ridership_{Base}$ = Baseline ridership (# of trips)
$Ridership_{Inc}$ = Ridership increase (percentage)
MSF = Mode shift factor (unitless)

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[71] The land-use multiplier is a unitless reduction factor (Vehicle-mile reductions per transit passenger mile) recommended by the APTA specific to transit that factors how transit enables higher densities and mixes 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.

[72] American Public Transportation Association. APTA Standards Development Program Recommended Practice. *Quantifying Greenhouse Gas Emissions from Transit*. APTA SUDS-CC-RP-001-09. August 14, 2009.

[73] Ibid.

[74] HDR and CLR Analytics System Metrics Group, Inc. *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.

[75] American Public Transportation Association. APTA Standards Development Program Recommended Practice. *Quantifying Greenhouse Gas Emissions from Transit*. APTA SUDS-CC-RP-001-09. August 14, 2009.

LU = *Land-use multiplier (unitless)*
TL = *Average regional H-W Trip Length (miles per trip)*
AVO = *Average vehicle occupancy (unitless)*

Step 8: Obtain increased transit trips (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 9: Obtain displaced private automobile trip CO_2 emission rates from the current version of EMFAC[76].
Step 10:Obtain transit CO_2 emission rates (if applicable)[77].
Step 11: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[78])*
$Transit_{ER}$ = *Transit emission rate (varies[79])*

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 for their 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

[76] 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 changes in fuel type and consumption associated with mode shift from private automobiles to transit.
[77] Ibid.
[78] 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
[79] Ibid.

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[80]. Thus, increased transit investment for commute ridership could displace, at best, only a fraction of total VMT.

Disruptive technologies, such as self-driving cars, Uber and Lyft rider 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 issue
- 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:

- 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 elements 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

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[80] CalTrans Division of Research, Innovation and System Information. *Methodologies to Convert Other Modes of Travel to Vehicle Miles Traveled (VMT).* July, 2015. Available at: http://www.dot.ca.gov/newtech/researchreports/preliminary_investigations/docs/modes_to_miles_preliminary_investigation_7-6-15_final.pdf

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 street, 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 last mile between transit station 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 strategy 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.[81]

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 data from regional and/or local bicycling and pedestrian master plan, region-specific study, or other empirical data sources.

b) Alternate Approach 1: Use most conservative elasticities[82] 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.

c) *Alternate* Approach 2: Use bike share increase data from Table 16, which associates the percent increase in commute bicycle trip mode share with each additional one mile of bicycle facilities per square mile.

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

Study	Population size[83]	Percent increase in bicycle commuting
Nelson and Allen (1997) [84]	20 big U.S. Cities with over 100,000 residents	0.069% per mile of bikeway per 100,000 residents
Dill and Carr (2003) [85]	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

[81] If the bicycle and pedestrian improvement strategy has a focus on local areas, same methodology can be applied to determine the percent increase in bike/pedestrian lane-miles in the specific areas.

[82] Elasticity is the percent increase in bicycling/pedestrian commute trips for every 1% increase in bicycling/pedestrian lane miles.

[83] 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.

[84] Nelson, A. C., and D. Allen (1997). If You Build Them, Commuters Will Use Them: Association Between Bicycle Facilities and Bicycle Commuting. In Transportation Research Record 1578, TRB, National Research Council, Washington, D.C., pp. 79–83.

[85] Dill, Jennifer and Theresa Carr (2003). “Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Tem, Commuters Will Use Them – Another Look.” TRB 2003 Annual Meeting CD-ROM.

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

Step 4: Estimate average regional H-W 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[86] 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[87])*

Trips = Regional H-W Trips (# of trips)

TL = Average regional H-W Trip Length (miles per trip)

Step 6: Obtain displaced private automobile trip CO_2 emission rates from the current version of EMFAC[88].

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

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[86] U.S. Department of Transportation, Federal Highway Administration. 2011. Summary of Travel Trends: 2009 National Household Travel Survey. Washington, DC.

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

[88] 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 changes in fuel type and consumption associated with mode shift from private automobiles to transit.

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.

Monitoring and Tracking

MPOs can track various metrics so they can ensure the strategy is implemented and works. These items include the following that MPOs may want to track:

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

Bike Share

Strategy Description

Bike share programs allow members to pick up a bike, ride to their destination, and leave it at a new location for a small fee. 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 program 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[89] for each city with planned bike share program and determine the number of planned bike share stations and population for each service area.

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 H-W trip lengths.

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[89] A bike share service area is the geographical area a bike share user can park the bike when they are 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.

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[90] 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 H-W 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 H-W Trip Length (miles per trip)

Step 8: Obtain displaced private automobile trip CO_2 emission rates from the current version of EMFAC[91].

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% of Bike Rides displace VMT for commutes or errands[92]

EMFAC = EMFAC CO_2 emission rate (grams per mile)

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 bike-related Infrastructures, such as bike lane, bike rack, and etc. However, these infrastructures are usually beyond the scope of bike-sharing program. Therefore, the effectiveness of bike sharing programs could be constrained by the readiness and availability of bike-related Infrastructures.

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[90] U.S. Department of Transportation, Federal Highway Administration. 2011. Summary of Travel Trends: 2009 National Household Travel Survey. Washington, DC.

[91] 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 changes in fuel type and consumption associated with mode shift from private automobiles to transit.

[92] Dill, Jennifer and Theresa Carr (2003). "Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Tem, Commuters Will Use Them – Another Look." TRB 2003 Annual Meeting CD-ROM

Bike commuters frequently use additional transportation modes for their 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., cities) either near home location or work place. As a result, potential bike commuters will need to plan longer travel time and pay premium for using bikes from multiple companies which may increase total commute cost.

In addition, bike sharing program users may worry about the protection of their privacy. Many shared bikes are installed with route tracking devices (e.g., GPS) to help company tracking the bike flow. However, it can be a big challenge to properly store and use these activity data. Currently, there is no specific regulations in this area and improper usage of activity data which harms people's privacy is very likely to adversely affect their 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 only 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[93]. Telecommute generally does not include flexible

[93] Susan Hand, Gil Tal, Marlon Boarnet, *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

or compressed work schedules[94], 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 work-related vehicle trips and 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 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 industries in the region that can participate in a telecommuting program?
- Are there potential populations for telecommuting for future SCS updates but currently not accounted for in the new SCS?
- What is the average travel distance for home-based work (HBW) trips in the region with and without telecommuting?[95]

Quantification Methodology

If a telecommuting strategy is considered by an SCS to reduce GHG emissions, the MPO needs to clearly describe the assumptions, quantification of GHG emission reduction, and implementation plan associated with the telecommute strategy that is in the proposed SCS (e.g., level of deployment, percent of workers use telecommute, industries 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 their workplaces in the long term due to promotion of telecommute or it may induce additional trips such as lunch or personal errands while

[94] 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.

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

an employee is working from home which may range from 3.7 to 6 miles (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 industry.

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

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

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

MPO can use their best practice in quantifying the impact of telecommute strategy on reducing regional VMT, given the above mentioned trip and emissions data needs and conditions are considered in the methodology.

Challenges, Constraints, and Strategy Implementation Tracking

Challenges and Constraints

MPOs should summarize foreseeable challenges in 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 MPO to refine categories of worker future 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 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, bicycle, and public transit due to reduced driving associated with reduced 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[96]:

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.

[96] Kristin Lovejoy, Susan Handy, Marlon Boarnet. *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

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:

- Reducing congestion by lowering the number of vehicles
- Lowering the overall VMT, ultimately cVMT (combustion VMT)
- Changes in fleet mix, such as reducing vehicle ownership and more zero emission vehicles (ZEV)
- Replacing private vehicles with car share vehicles
- 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, are a 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[97].

a) Preferred Approach: Use data from regional and/or local TNC 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.

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[98], while 10% of individuals aged 21+ in metropolitan areas of North America would become members if it were more convenient[99].

a) Preferred Approach: Use data from regional and/or local TNC 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*

[97] Celsor, C. et al., Where does Car-Sharing Work? Using GIS to Assess Market Potential. 2007 Annual Meeting of the Transportation Research Board
[98] Transportation Research Board, Transit Cooperative Research Program. Car-Sharing: Where and How It Succeeds. TCRP Report 108. 2005
[99] Millard-Ball, A., Murray, G., Ter Schure, J., and Fox, C., TCRP Report 108, Car Sharing: Where and How it Succeeds; Shaheen, S., Cohen, A., Robert, J., Car Sharing in North America: Market Growth, Current Developments, and Future Potential in R. Hampshire, Achieving the promise of the sharing economy: The case of peer-2-peer carsharing.

Adoption Rate$_{CS}$ = Car sharing adoption rate for region/TAZ

Step 5: Estimate VMT reductions from vehicles discarded or shed by car sharing members.
Research by the University of California at Berkeley (TSRC)[100] 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[101]. 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 TNC 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[102].

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

- Total VMT$_{Shed}$ = Total VMT from shed vehicles in region/TAZs (miles/year)
Membership Population$_{CS}$ = Number of car sharing members in region/TAZs
- VMT$_{Memb\ Shed}$ = 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[103].

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[100] E. Martin, S. Shaheen, "The Impacts of Car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions: An Analysis of Five North American Cities" TSRC, UC Berkeley, 2016
[101] E. Martin, S. Shaheen, "Greenhouse Gas Emission Impacts of Carsharing in North America" MTI, San José State University, 2010
[102] ibid
[103] 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

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 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[104].

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[105].

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

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 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

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(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.

[104] CARB calculated from E. Martin, S. Shaheen, "Greenhouse Gas Emission Impacts of Carsharing in North America" MTI, San José State University, 2010

[105] ibid

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.[106]

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[107].
b) Alternate Approach: Obtain CO_2 emission rates for shed private automobiles from the current version of EMFAC[108] 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.

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

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)

[106] ibid

[107] 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 changes in fuel type and consumption associated with mode shift from private automobiles to transit.

[108] ibid.

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 population 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) [109] 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 e-miles/d/veh[110]. 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.

As PHEVs can operate in gasoline and electric operating modes, the strategy would serve to maximize PHEV operation in electric operating mode and minimize their

[109] 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
[110] CARB. 2017 Unpublished.

operation in gasoline mode, thereby reducing tailpipe CO_2 emissions. Providing EV chargers at employee workplaces would help to extend the electric operation range of PHEVs used by employees who use EVs for commuting purposes. Specifically, the strategy assumes PHEV batteries are fully charged prior to an employee beginning a commute trip to their workplace from home, as most PHEVs charge at home, where the owner can qualify for low-cost night time charging which makes the electricity cheaper than gasoline. To facilitate PHEVs operating in electric mode on the employee's return commute trip to their home from workplace, the PHEV batteries are "topped off" during work hours through the EV charging infrastructure installed under this strategy. In addition, as the strategy would be limited to employees where EV vehicle charging infrastructure is installed due to the strategy and would not be available to the general public, it is anticipated the strategy would not affect PHEVs driven by the general public and would not lead to induced VMT nor trips.

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

1. A one-time financial subsidy offered to employers for the purchase and installation of workplace EV vehicle charging infrastructure.
2. When gasoline is cheaper than electricity on a per-mile basis, on-going incentives offered to employers to subsidize[111] PHEV-driving employees to charge their cars with EV vehicle infrastructure to help disincentivize the operation of PHEVs in 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:

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[111] 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 utility electricity rates 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.

- The number of new workplace EV charging stations
- The number of PHEVs participating in the program

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:

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

Following is the basic analytical steps that MPOs can consider when estimating emissions associated with the installation of workplace EV chargers. The overall approach is to determine the increase PHEV mileage shifted from gasoline to electricity (e-miles) due to PHEV workplace charging at EV charging connectors installed by the strategy.

The estimate of GHG emission reductions from increased PHEV e-miles due to the the strategy can be based upon two different initial approaches based on how the strategy is set up:

a) Set up of the strategy based on the number of EV charging connectors installed (Steps 1a through 3a)

   Estimate the number of population of PHEVs in region → Estimate the number of PHEVs per charging connector → Estimate the number of PHEVs in the region that could use workplace EV Charging Connectors → Estimate average VMT shift per PHEV from gas to electricity (e-miles) → Estimate total regional VMT shift from gas to electricity (e-miles) → Estimate CO_2 emission reductions from PHEV e-miles.

b) Set up of the strategy based on the number of PHEVs in the region that could use installed EV charging connectors (Steps 1b through 3b)

Estimate population of PHEVs in region → Estimate number of PHEVs per charging connector → Estimate number of EV Charging Connectors to install→ Estimate VMT shift from gas to electricity (e-miles) → Estimate CO_2 emission reductions from PHEV e-miles.

Both of these approaches are described in detail below.

a) Estimate the number of PHEVs in Region based on the number of EV Charging Connectors Installed by the Strategy

Step 1a: Identify number of workplace EV charging connectors ($Connector_{Region}$) to install in the region as part of strategy.

Step 2a. Estimate the average number of PHEVs per charging connector installed ($PHEV_{Connector}$).

a) Preferred Approach: Use regional data, studies, or other empirical data sources.
b) Alternate Approach: Assume seven (7) PHEVs per charging connector based on National Renewable Energy Laboratory (NREL) data[112].

Step 3a: Identify the number of PHEVs in the region that could use EV charging connectors installed as a result of the strategy ($PHEV_{Region}$) based on the the number of regional EV charging connectors installed in the region as a result of the strategy (Step 1a) and the average number of PHEV's per charging connector (Step 1a). Proceed to Step 4.

$$PHEV_{Region} = Connector_{Region} * PHEV_{Connector}$$

$PHEV_{Region}$ = Regional PHEV population affected by strategy
$Connector_{Region}$ = Number of regional EV charging connectors installed in the region as part of the strategy (Step 1a)
$PHEV_{Connector}$ = Average number of PHEVs per charging connector (Step 2a)

b) Estimate number of PHEVs in Region based on the number of PHEVs in the State

Step 1b: Estimate the number of PHEVs in the region that could use EV charging connectors installed as a result of the strategy ($PHEV_{Region}$)

[112] 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.

a) Preferred Approach. Use local regional data, studies, or other empirical data sources to estimate the number of PHEVs in the region that could use EV charging connectors installed as a result of the strategy.
b) Alternative approach: Estimate the number of PHEVs in the region ($PHEV_{Region}$) by applying the MPO's fraction of statewide VMT ($VMT\ Fraction_{Region}$) to the statewide PHEV population ($PHEV_{State}$)[113].

Step A: Obtain the MPO's fraction of statewide VMT ($VMT\ Fraction_{MPO}$) from the most recent version of EMFAC. Table 18 presents data from EMFAC2014.

Step B: Estimate statewide PHEV population ($PHEV_{State}$) in 2035. There will be about 1,000,000 PHEVs (1,098,896) in the State as of in 2035[114].

Step C: Multiply the MPO's fraction of statewide VMT (Step A) and statewide PHEV population (Step B) to obtain the number of PHEVs in the region ($PHEV_{Region}$).

$$PHEV_{Region} = VMT\ Fraction_{MPO} * \ PHEV_{State}$$

$PHEV_{Region} = Regional\ PHEV\ population\ affected\ by\ strategy$
$VMT\ Fraction_{MPO} = MPO\ Fraction\ of\ Statewide\ VMT\ (from\ EMFAC)$
$PHEV_{State} = Statewide\ PHEV\ population$

[113] As obtaining PHEVs by county from DMV records may be difficult and/or infeasible, the approach is based on apportioning LDV VMT fraction for each county from the Statewide PHEV population (it is assumed counties will have the same proportion of PHEVs as the State), The Statewide PHEV was estimated in CARB 2017 ACC Midterm Review.

CARB. 2017. California's Advanced Clean Cars Midterm Review. Summary Report for the Technical Analysis of Light Duty Vehicle Standards. California Air Resources Board, Sacramento, CA. https://www.arb.ca.gov/msprog/acc/mtr/acc_mtr_finalreport_full.pdf.

Figure 12 on page ES-51 provides annual sales up to 2025. The sales from 2026-2035 are assumed to be the same as 2025 because the regulatory requirements for these years are the same as 2025. The sales each year are multiplied by survival rates (fraction surviving by age) from CARB 2014 to get obtain the surviving total population.

CARB 2014. EMFAC 2014 Vol III Technical Documentation. Chapter 3.3.3.1.3.3. Figure 3.3-8. California Air Resources Board. Sacramento, CA. https://www.arb.ca.gov/msei/downloads/emfac2014/emfac2014-vol3-technical-documentation-052015.pdf .

[114] CARB 2017 op. cit.

Table 17. Fraction of State VMT for Each Metropolitan Planning Organization

Area	Fract of State VMT
AMBAG	0.017
BCAG	0.004
COFCG	0.016
KCAG	0.004
KCOG	0.027
MCAG	0.008
MCTC	0.005
MTC	0.187
None	0.033
SACOG	0.063
SanDAG	0.085
SBCAG	0.012
SCAG	0.480
SCRTPA	0.006
SJ COG	0.022
SLOCOG	0.009
StanCOG	0.010
TCAG	0.009
TMPO	0.001

When the strategy is set up based on the number of PHEVs in the region that could use installed EV charging connectors, Steps 2b and 3b should be used to allow the MPO to identify the number of workplace EV charging connectors that will need to be installed as part of the strategy. Users should proceed to Step 4 using the output from Step 1b.

Step 2b: Estimate the average number of PHEVs per charging connector installed ($PHEV_{Connector}$).

a) Preferred Approach: Use regional data, studies, or other empirical data sources.
b) Alternate Approach: Assume seven (7) PHEVs per connector based on National Renewable Energy Laboratory (NREL) data[115].

[115] Melaina and Helwig. 2014. *Op cit*.

Step 3b: Estimate number of workplace EV charging connectors to install in the region as part of the strategy ($Connector_{Region}$) based on the number of PHEVs in the region affected by strategy (Step 1b) and the average number of PHEVs per charging connector installed (Step 2b).

$$Connector_{Region} = \frac{PHEV_{Region}}{PHEV_{Connector}}$$

$Connector_{Region}$ = *Number of EV Charging Connectors required in region*
$PHEV_{Region}$ = *Regional PHEV population affected by strategy (Step 1b)*
$PHEV_{Connector}$ = *Number of PHEVs per EV Charging Connector (Step 2b)*

Estimate Increases in PHEV e-miles from the Number of PHEVs in the Region

Step 4: Estimate the average increase in e-miles per PHEV ($PHEV_{e\text{-}miles}$) 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 e-miles per day per PHEV using a workplace EV charging connector[116].

Step 5: Estimate the total increased PHEV e-miles in the region ($e\text{-}miles_{Region}$) resulting from strategy implementation based on the number of PHEVs in the region affected by the strategy (Step 3a or 1b) and the average increase in e-miles per PHEV for the region (Step 4)

$$e - miles_{Region} = PHEV_{Region} * \ PHEV_{e-miles}$$

$e\text{-}miles_{Region}$ = *Total increased PHEV e-miles for the region*
$PHEV_{Region}$ = *Regional PHEV population affected by strategy (Step 3a or 1b)*
$PHEV_{e\text{-}miles}$ = *Average increase in e-miles per PHEV for the region (Step 4)*

[116]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.

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[117].

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 e-miles for the region (Step 5) and decreased PHEV gasoline consumption emission factor (Step 6).

$$-CO_{2\ PHEV} = e - miles_{Region} * \ Emission\ Factor_{Gas}$$

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

Challenges, Constraints, and Strategy Implementation Tracking

Challenges and Constraints

- The goal of the strategy is to increase PHEV e-miles per day; not to increase purchases of PHEV nor BEVs. That is covered by other strategies.
- 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). 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.

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

[117] CARB Unpublished Data *op cit.* Internal CARB analysis indicates the State average CO_2 emissions for PHEV operation on gasoline in 2016 is 198 grams per mile. PHEV tailpipe emissions on electricity are taken to be 0 g/mi.

- 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 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[118]:

- 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 VMT
- Reduced vehicle trips
- Reduced vehicle hours traveled (VHT) (i.e., searching time for parking)
- Changes in mode share

[118] Handy, S., M. Boarnet, 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

Trip and Emissions Data Needs

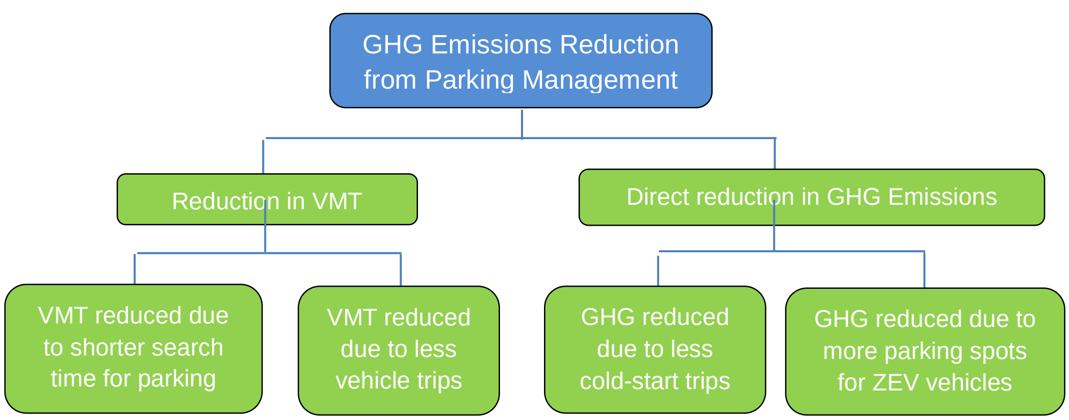
In addition to the general input data and assumptions for off-model strategies listed in Table 13 of the introduction section, the following is a list of specific conditions and factors MPOs should consider and document for parking management strategies:

- 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

Quantification Methodology

Figure 4 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 4. 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 they should reflect the elements 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}: $Average\ travel\ speed\ on\ local\ street\ (mph)$
t_{saved}: $Time\ saved\ from\ parking\ (hour)$

Step 2: Quantifying VMT reduced due to less vehicle trips:

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

$-VMT_{vt_{work}}$: $VMT\ reduced\ due\ to\ reduction\ of\ work\ trips\ (mile)$
d_{HBW}: $Average\ trip\ length\ of\ HBW\ trips\ \left(\frac{mile}{day}\right)$
N_{sov}: $Number\ of\ SOV\ commuters\ who\ shift\ to\ alternative\ modes$

Assume on average 4 work days and 52 weeks per year

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

$-VMT_{vt\_other}$: $VMT\ reduced\ due\ to\ reduction\ of\ non-work\ related\ trips\ (mile)$
d_{other}: $Average\ trip\ length\ of\ non-work\ trips\ \left(\frac{mile}{day}\right)$
N_{other}: $Number\ of\ non-work\ trips\ that\ switch\ from\ SOV\ mode\ to\ alternative\ modes$

Assume on average 4 work days and 52 weeks per year

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

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

$-GHG_{cold-start/vehicle}$: $Net\ GHG\ emission\ reduction\ for\ one\ less\ cold-start\ vehicle$
$ER_{CO_{2_{cold-start}}}$: $Cold-start\ emission\ rate\ for\ CO_2\ (\frac{gram(s)}{second})$
$t_{warm-up}$: $Average\ time\ for\ light-duty\ vehicles\ warm\ up\ (seconds)$

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

$$-GHG_{ZEV} = ER_{CO2\_ICE} * TR_{ZEV}$$

ER_{CO2_ICE}: $Average\ CO2\ emission\ rate\ of\ the\ ICE\ vehicles\ replaced\ by\ ZEV$
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 potential have 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, direct transit strategy (e.g., more frequent transit service) can also motivate traveler in the same planning area to switch from auto mode to 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 18 lists examples of potential monitoring steps and tracking system that MPOs can considering regarding parking management strategies.

Table 18. 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 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 development 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.[119] 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 November 2018, the CVRP has over $ 23 million in funds remaining[120].

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

Two potential approaches for distribution of incentives could be available:

1. Point-of-Sale: Subsidies from the incentive program are applied to the purchase price of the new car at the time of new vehicle purchase. The dealer would be responsible for handling and submitting the incentive program paperwork and documentation.
2. After-Purchase: Rebates from the incentive program are provided to consumers upon registration of new ZEV with DMV. The consumer would be responsible for obtaining, handling, and submitting the incentive program paperwork and documentation.

Objectives

Electric Vehicle Incentive strategies can reduce GHG emissions as follows:

[119] 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 CO2 emission factors than new cars).

[120] California Clean Vehicle Rebate Project, CVRP Funding Status. Available at: https://cleanvehiclerebate.org/eng/rebate-funding-status. Accessed November 1, 2018.

- Increasing new ZEV purchases
- Reducing new non-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
- Individual subsidy/rebate amount
- 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. If MPOs have an alternative approach to quantifying GHG benefits, the MPO should document their own specific methodology and demonstrate how each element of the off-model framework from the updated guidance is addressed and satisfied. If an MPO elects to implement a strategy and quantification methodology based on a strategy currently employed by other MPO(s), the MPO must cite all the applicable resources and demonstrate why the methodology, assumptions, and demographics borrowed from the external MPO is applicable to the local MPO.

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[121].

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

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

Step 3: Identify 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 average trip length (*Average Trip Length*). Use the daily usage for a vehicle (miles per day per vehicle) from EMFAC.

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

$$ZEV\ VMT = Total\ Program\ ZEV\ [Step\ 3] * Average\ Trip\ Length\ [Step\ 4]$$

ZEV VMT =	*Average VMT 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 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[122] and Fuel Economy.gov for the new EV purchased.

Step 7: Calculate County fraction of EV purchase. The MPO may not claim the credit for an EV's lower emissions. Only the fraction of the cost that the MPO provided.

$$County\ Benefit\ Fraction = \frac{Incentive\ amount}{Total\ Purchase\ Price}$$

Incentive amount =	*Subsidy rebate rate from Step 2*
Total purchase price	*Total automobile purchase price.*

[121] CARB. Mobile Source Emissions Inventory. Last updated: March, 2018. Available at: https://www.arb.ca.gov/msei/msei.htm

[122] Available at: https://www.arb.ca.gov/msei/msei.htm

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

$$GHG\ Reductions = ZEV\ VMT\ [Step\ 5] * County\ Benefit\ Fraction\ [Step\ 7] * (Non\ ZEV\ EF - ZEV\ EF)[Step\ 6]$$

GHG Emission Reductions =	*GHG emission reductions from ZEV's purchased through the subsidy/rebate program g/d/veh*
ZEV VMT =	*VMT from ZEV's purchased through the subsidy/rebate program [Step 5] mi/d/veh*
County Benefit Fract	*County Benefit fraction Step 7*
Non-ZEV EF =	*Average regional GHG emission factor from EMFAC for new-non-ZEVs [Step 6] g/mi*
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, as they would be responsible for 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, as they would be responsible for 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 they may 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
- 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[123]

Monitoring and Tracking

- Amount of total funding in program incentive program
- Amount of individual rebate/subsidies
- 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 ZEV

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[124]. Building upon the ITS technologies, Transportation System Management (TSM) specifically focuses on reducing traffic congestion by

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[123] 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).

[124] USDOT. ITS Research Fact Sheets – Benefits of Intelligent Transportation Systems. https://www.its.dot.gov/factsheets/benefits_factsheet.htm

increasing the person-trip capacity of existing transportation system. In general, TSM/ITS refers to a broad range of strategies that aim to reduce GHG emissions and increase transportation system efficiency through congestion mitigation, traffic smoothing, and speed management. Table 19 lists common examples of TSM/ITS related strategies.

Table 19. 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 • Connected autonomous 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 strategy for implementation to achieve these objectives.

Objectives

Generally, TSM/ITS can reduce GHG emissions by:

- Optimizing travel speeds
- Relieving congestion
- Improving driving behavior

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[125] 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, cost per traveler who utilizes the travel information site(s)]?

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

- 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 CO2 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.

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

Step 4: Gather the average hourly speed (S_i), the congested VMT and daily volume (V_i) data of the affected $corridor_i$.

Step 5: Based on proposed number of TSM-related systems Estimate the impact of the proposed TSM strategy on travel speed based on finding in empirical literature (P_{imp}).

Step 6: Estimate the reduction of GHG emission reduction ($\triangle_{GHG}$) based on the latest EMFAC model.

$$\triangle\ GHG_{TSM} = \sum_{i}^{n} V_i * \triangle_{GHG} * VMT_{cong\_i}$$

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.

Monitoring/Tracking

For progress and effectiveness monitoring of TSM/ITS strategy, MPO can consider conduct traffic survey 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 these or related data information are collected, MPO can update the initial analysis on the impact on reducing GHG emissions to track the effectiveness and performance of the strategy.

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 benefits for employer or employees to participate in a vanpool program are available?

- 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 vanpool for future SCS updates but currently not accounted for in the new 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 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 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 trips 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 vans, 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[126], 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 H-W 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 Trips Reduced * Adjusted Miles/Trip = Auto 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.[127]

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

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

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[126] Methods to Find the Cost-Effectiveness of Funding Air Quality projects, May 2005, California Air Resources Board

[127] 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 changes in fuel type and consumption associated with mode shift from private automobiles to transit.

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

Appendix F: Methodology to Calculate CO_2 Adjustment to EMFAC Output for SB 375 Target Demonstrations

Background:

In 2010, ARB established regional SB 375 greenhouse gas (GHG) targets in the form of a percent reduction per capita from 2005 for passenger vehicles using the ARB Emission Factor model, EMFAC 2007. 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. ARB 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, ARB has released two subsequent versions, EMFAC2011[128] and EMFAC2014[2].

ARB has improved the carbon dioxide (CO_2) emission rates in EMFAC2011 and EMFAC2014, based on recent emission testing data 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 and EMFAC2014 compared to EMFAC2007.

Purpose:

Some metropolitan planning organizations (MPOs) used EMFAC 2007 to quantify GHG emissions reductions from their first Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS); others used EMFAC 2011. As MPOs estimate GHG emissions reductions from subsequent RTP/SCSs, they will use the latest approved version of EMFAC, but using a different model will influence their estimates and their ability to achieve SB 375 targets. The goal of this methodology is to hold each MPO to the same level of stringency in achieving their SB 375 targets regardless of the version of EMFAC used for its second RTP/SCS.

ARB 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 second 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

[128] EMFAC2011 was approved by USEPA in March 2013.

[2] EMFAC2014 is under review for USEPA approval.

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.

Applicability:

The adjustment is applicable when the first RTP/SCS was developed using either EMFAC2007 or EMFAC2011 and the second 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 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.

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.

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.