TECHNICAL EVALUATION OF THE GREENHOUSE GAS EMISSIONS REDUCTION QUANTIFICATION FOR THE MERCED COUNTY ASSOCIATION OF GOVERNMENTS' SB 375 SUSTAINABLE COMMUNITIES STRATEGY

AUGUST 2018

CALIFORNIA AIR RESOURCES BOARD

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EXECUTIVE SUMMARY

The Sustainable Communities and Climate Protection Act of 2008 (SB 375) calls for the California Air Resources Board (CARB) to accept or reject the determination of each Metropolitan Planning Organization (MPO), that their Sustainable Communities Strategy (SCS) would, if implemented, achieve the passenger vehicle greenhouse gas (GHG) emissions reduction targets (targets) for 2020 and 2035, set by CARB.

For Merced County Association of Governments (MCAG), the MPO for the County of Merced, CARB set per capita GHG emissions reduction targets for the region of 5 percent in 2020 and 10 percent in 2035 from a 2005 base year. The MCAG Board adopted a final Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS) on September 25, 2014. The 2014 SCS projected that the region would, if implemented, achieve the 2020 GHG emissions reduction target, but would not achieve the 2035 GHG emissions reduction target. Because the 2014 RTP/SCS would not achieve for the 2035 target, the plan would not qualify as an SCS under SB 375. For this reason, MCAG initiated a reevaluation of the 2014 SCS, which resulted in an amendment to their SCS (Amended SCS), adopted May 19, 2016. MCAG transmitted a complete submittal of their Amended SCS and GHG emissions quantification documentation to CARB for review on April 11, 2018.

Merced County is in the San Joaquin Valley (Valley), a significant agricultural region of the State with a population of about 256,000 people. It is located just north of Madera County and south of Stanislaus County, consisting of about 2,000 square miles and is one of the richest agricultural regions in the United States. The transportation system is primarily auto-dependent, however Merced County Transit offers 15 fixed route lines including demand response services. Development in the region is primarily low density, single-family residential located within the 6 incorporated cities.

The Amended SCS prioritizes preservation of environmental and agricultural land and development in urban centers with connections to transportation corridors. The land use strategy of the SCS focuses on efforts within local jurisdictions to increase connectivity and the mix of land uses that will help provide more housing choices for residents and decrease travel distances to destinations. The Amended SCS also includes increased investments in public transportation projects, as well as non-motorized transportation options that aim to meet the needs of residents. Additionally, continued investment in vanpools and rideshare will continue to be an effective alternative to single occupant vehicle travel for some residents.

This report represents CARB staff's evaluation of MCAG's Amended SCS and GHG emissions reduction determination, and describes methods used to evaluate the GHG emissions quantification. CARB staff has concluded that MCAG's Amended SCS, if implemented, would achieve the region's GHG emissions reduction targets of 5 and 10 percent reduction in 2020 and 2035, respectively.

This conclusion is based on CARB staff's independent assessment of multiple factors, including the sensitivity of the MPO's travel demand model, and the types of projects and strategies in the SCS that support compact development, and qualitative evidence from SCS performance indicators that indicate the region's ability to reduce per capita emissions.

I. MERCED COUNTY ASSOCIATION OF GOVERNMENTS

In California, Metropolitan Planning Organizations (MPO) are responsible for preparing and updating Regional Transportation Plans (RTP)[1] that include a Sustainable Communities Strategy (SCS),[2] demonstrating a reduction in regional greenhouse gas (GHG) emissions from automobiles and light-duty trucks to meet regional targets set by the California Air Resources Board (CARB).

Merced County Association of Governments (MCAG) is the federally designated MPO and State designated Regional Transportation Planning Agency (RTPA) for Merced County. MCAG member agencies include Merced County and the 6 incorporated cities of Atwater, Dos Palos, Gustine, Livingston, Los Banos, and Merced. MCAG's 11 member Governing Board is composed of 5 Merced County supervisors, and 1 representative from each city council. The Citizens Advisory Committee, Technical Planning Committee, and Technical Review Board, along with input collected during public workshops, informed the development of the 2014 SCS (and subsequent 2016 RTP/SCS Amendment (Amended SCS).

A. Background

The MCAG region encompasses approximately 2,000 square miles in the central San Joaquin Valley and is bordered by Stanislaus County to the north, Fresno and Madera Counties to the south, Mariposa County to the east, and Santa Clara and San Benito counties to the west. The region is primarily rural, agricultural land with 46 percent of the land area dedicated to farmland.[3] The region spans from the Coastal Ranges (Diablo Range) to the foothills of the Sierra Nevada, consisting of predominantly flat topography with flood plains from the San Joaquin River that support its agricultural economy. Merced County's 255,793 residents[4] are mostly concentrated in the 6 cities of Atwater, Dos Palos, Gustine, Livingston, Los Banos, and Merced. Residential development throughout Merced County is mostly suburban or rural in nature consisting of low density, single-family residential, which constitutes approximately 77 percent of the existing housing supply.[5]

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[1] An RTP is a federally required plan to finance and program regional transportation infrastructure projects, and associated operation and maintenance for the next 20 years.

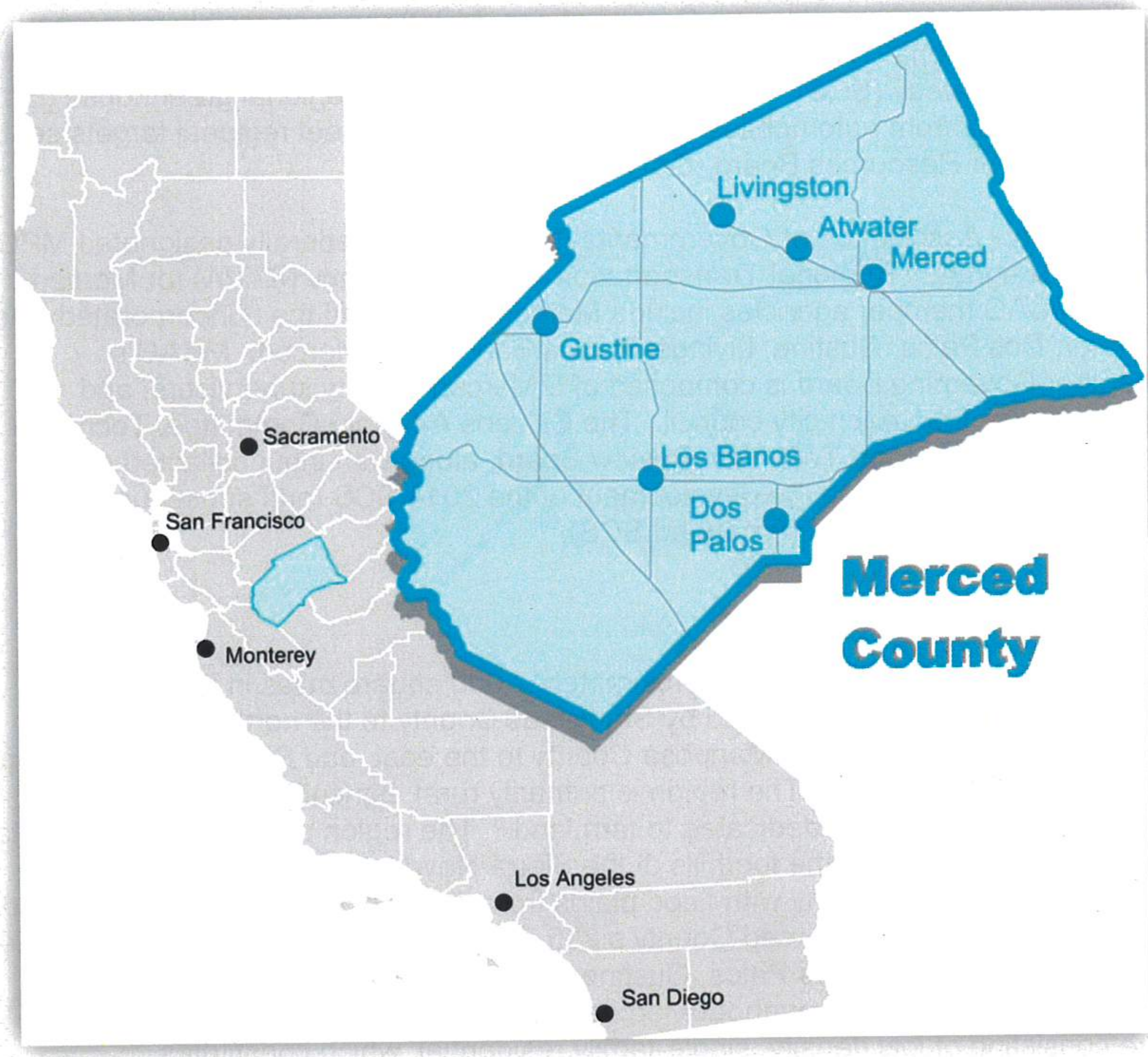
[2] The SCS sets forth a forecasted development pattern for the region which, when integrated with the transportation network and other transportation measures and policies, will reduce the GHG emissions from automobiles and light trucks. It shall include identification of the location of uses, residential densities and building densities, information regarding resource areas and farmland.

[3] APPENDIX B. MCAG Modeling Data Table

[4] United States Census Bureau, 2006-2010 American Community Survey 5-Year Estimates.

[5] APPENDIX B. MCAG Modeling Data Table

Figure 1: MCAG Context Map



Source: MCAG Amended SCS (May 19, 2016).

The largest city, and only urbanized area[6] within Merced County, is the City of Merced with almost 79,000 residents, or about one third of the region's total population. The second largest city within the region is Los Banos, which consists of 36,000 residents. The remaining population lives within the cities of Atwater and Livingston along State Route (SR) 99, Gustine and Dos Palos to the south and the remaining unincorporated area of the region. Approximately 90,000 residents live in the unincorporated areas of Merced County. As of 2010, over 13 percent or more than 170,000 acres within the region are protected wildlife areas or private conservancies.[7]

SR 99 is a major transportation corridor for movement of agricultural products and other commercial goods, and also serves as a major link for recreation-bound traffic throughout the region.[8] The SR 99 corridor runs north-south through the eastern part of Merced County through the cities of Merced, Livingston and Atwater. Interstate 5 (I-5) runs parallel to SR 99 through the western half of the region through the cities of Los Banos and Gustine. Both of these routes are sources of heavy truck travel serving as primary corridors, with most traffic served by SR 99 and I-5, for freight movement throughout the State. Other primary transportation facilities in the region include SR 152, 165, 33, 140, and 59 (Figure 2).

Between 2010 and 2015, the unemployment rate in the region has increased slightly from 14 to 16 percent.[9,10] The top five industries by employment are: (1) educational services, health care, and social assistance, (2) agriculture, forestry, fishing, hunting, and mining (3) manufacturing, (4) retail trade and (5) arts, entertainment, recreation, accommodation and food services. The largest employers within the region include: Foster Farms, Merced County Office of Education, and Mercy Medical Center – Merced.[11] All three of these major employers are served by transit.

B. Transportation Planning in the Region

MCAG develops an RTP/SCS, a long-range planning document, to integrate the growth policies of local governments in the region and the transportation system needed to support that growth. For the 2014 SCS, MCAG developed the plan in coordination with its member cities and Merced County, transportation providers, facility operators, appropriate federal, State, and local agencies, environmental resource agencies, air district, pedestrian and bicycle representatives, and adjoining MPO/RTPAs.

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[6] The US Census Bureau defines the term urbanized area as any area with a population of 50,000 or greater.
[7] County of Merced. (2012). 2030 Merced County General Plan. https://www.co.merced.ca.us/DocumentCenter/View/6766
[8] Caltrans. (2008) State Route 99 Corridor System Management Plan San Joaquin County Area. http://www.dot.ca.gov/d10/tcr-csmp/sr99/FinalSJ-99CSMP103108.pdf
[9] United States Census Bureau, 2006-2010 American Community Survey 5-Year Estimates.
[10] United States Census Bureau, 2011-2015 American Community Survey 5-Year Estimates.
[11] Employment Development Department. (2018). Major Employers in Merced County. http://www.labormarketinfo.edd.ca.gov/majorer/countymajorer.asp?CountyCode=000047

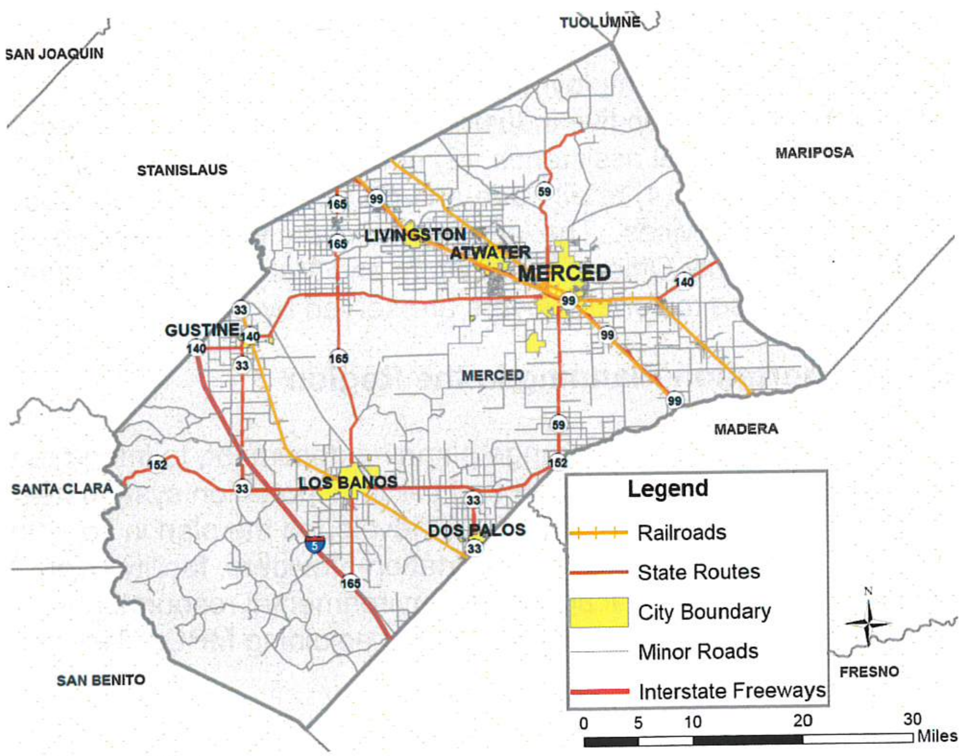
Transportation Systems

Merced County's transportation system is primarily concentrated within the incorporated cities of Merced, Livingston, Atwater, Los Banos, Dos Palos, and Gustine, however it is also served regionally by SR 99, I-5, and Amtrak. The transportation network consists of freeways, highways, local roadways, transit, rail, and bicycle/pedestrian facilities. The following section describes the existing transportation network in the MCAG region.

Roadways

MCAG has approximately 3,000 miles of freeway, arterial, collector, and local general purpose lanes. There are 6 state highways in Merced County and 1 interstate freeway, with most traffic served by SR 99 and I-5, both of which are heavily traveled and bisect Merced County (Figure 2).

Figure 2: MCAG Map of Roadways



Source: CARB.

The MCAG region is reliant on the roadway system for both residents and goods movement. With respect to goods movement, Merced County experiences a high volume of truck traffic, primarily originating in or passing through Merced County along SR 99 and I-5.

Transportation Demand Management

MCAG provides guidance and resources to regional employers that are required to comply with the San Joaquin Valley Air Pollution Control District's Employer Trip Reduction Implementation Plan (eTRIP) Rule 9410. This program requires employers of over 100 employees to encourage employees to reduce single-occupancy vehicle trips through strategies like providing preferential parking for vanpools and rideshare, and bicycle parking.

dibs

SMART TRAVEL. **YOUR WAY.**

Source: http://www.mcagov.org/229/Commute-Connection

Dibs, is a transportation demand management program provided by Merced, San Joaquin, and Stanislaus counties. Dibs serves commuters and employers in the three-county region by providing a free ride-matching system for carpoolers and vanpoolers, transit and tax credit information, commuter subsidies, and an emergency ride home program.

THE BUS

Source: http://www.mercedthebus.com/

Vanpooling is a viable transportation option for many residents in the MCAG region. Dibs and California Vanpool Authority (CalVans) help to operate over 120 vanpools, with over 880 registered participants.[12,13,14]

Transit and Rail

Merced County Transit – "The Bus" – provides public transit service throughout Merced County through a Joint Powers Agreement between Merced County and the 6 cities within the region. The Bus serves the entire County of Merced with 6 fixed routes in the City of Merced, one route operating to UC Merced, 2 fixed routes in Atwater, two commuter routes between Winton and Merced, and one commuter route from Merced to Los Banos. In addition to fixed-route service, The Bus operates three intercity routes and two rural deviated fixed routes, which provide demand response

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[12] Provided by Dibs Staff via email correspondence on March 1, 2018.
[13] Dibs. (2017). 2016-2017 Community Report. https://www.dibsmyway.com/wp-content/uploads/reports/2016-2017/index.html
[14] Calvans. (2017). Calvans August Newsletter. http://www.calvans.org/sites/default/files/downloadable-pdfs/events/Low%20Res_August%202017_Newsletter.pdf

service to rural communities. Los Banos is served by a general Dial-A-Ride Service, while complimentary curb-to-curb paratransit is available throughout Merced County through a reservation service. The system operates 42 buses assigned to fixed routes while 22 buses provide paratransit service. The Yosemite Area Regional Transportation System operates a fixed route service, which passes through Merced County, from the City of Merced into Yosemite National Park. There are no areas within Merced County served by high-quality transit.[15]

In August 2017, MCAG adopted a five year Short Range Transit Plan, which is the primary planning document for administering public transit and paratransit services within Merced County. The plan includes a description of existing transit services, passenger survey results, a service alternatives analysis, financial considerations, and a marketing plan. This plan assessed the efficiency of transit service and provided recommendations to improve services based upon rider and community input including expanded evening service, service area expansion and route revisions, and the need for additional bus stops. The Transit Joint Powers Authority for Merced County is currently in the process of updating their transit facility, which will provide facilities for fueling, washing, maintenance, and administrative functions all at one site, with construction to be complete by the end of 2018.[16]

MCAG is currently served by Amtrak rail service, with one station in the City of Merced. Amtrak provides rail access to other cities in the San Joaquin Valley, such as Fresno, as well as outside the Valley, including Oakland in the Bay Area. As part of California's expected high-speed rail system connecting San Diego to Sacramento, the High Speed Rail Authority has planned a stop in Downtown Merced along 16th Street between Martin Luther King Jr. Way and G Street. This station is expected to connect to existing local and regional transit and rail systems.[17]

Active Transportation

MCAG adopted a Regional Bicycle Plan in 2008 to connect major destinations and bikeway systems in local communities. All six cities within Merced County have a Bicycle Plan. Notably, the *City of Merced 2013 Bicycle Transportation Plan* outlines the most extensive bike path system within Merced County. Currently, Class I bike paths, exclusive for cyclists and pedestrians, run along portions of Black Rascal and Bear

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[15] Defined in SB 375 as including either a major transit stop (CA Public Resource Code Section 21064.3), or high-quality transit corridor with fixed route bus service with service intervals no longer than 15 minutes during peak commute hours.
[16] Merced County Association of Governments. (2017). Final Report Merced County 2017/18 – 2021/22 Short Range Transit Plan. https://www.mcagov.org/DocumentCenter/View/1348/Merced-SRTP-FINAL-Report-with-Appendices?bidId=
[17] California High-Speed Rail Authority. (2015). http://www.hsr.ca.gov/

Creeks, while Class II bike lanes, which provide restricted right-of-way on streets, run within the urban area of Merced.[18]

Transportation Funding

RTPs must be financially constrained, meaning that funding for planned transportation projects must be reasonably foreseeable. Funding for transportation projects comes from federal, State, and local sources, including federal transportation funding legislation, fuel taxes, license fees, and developer-paid impact fees.

MCAG includes a constrained transportation list with total available funding of 1.2 billion for the planning period 2014-2040. Funding for the projects listed in the Amended SCS comes from a combination of federal (22 percent), State (58 percent), and local (19 percent) sources.

The Amended SCS allocates almost $1.2 billion to transportation investments. Specifically, it dedicates 45 percent of the total budget to public transit including bus and rail ($526 million), 23 percent for highways and road expansion ($272 million), 18 percent for bike, walk, air, and ridesharing ($210 million), and 14 percent for local road maintenance ($163 million). Figure 3 summarizes the funding allocation by mode.

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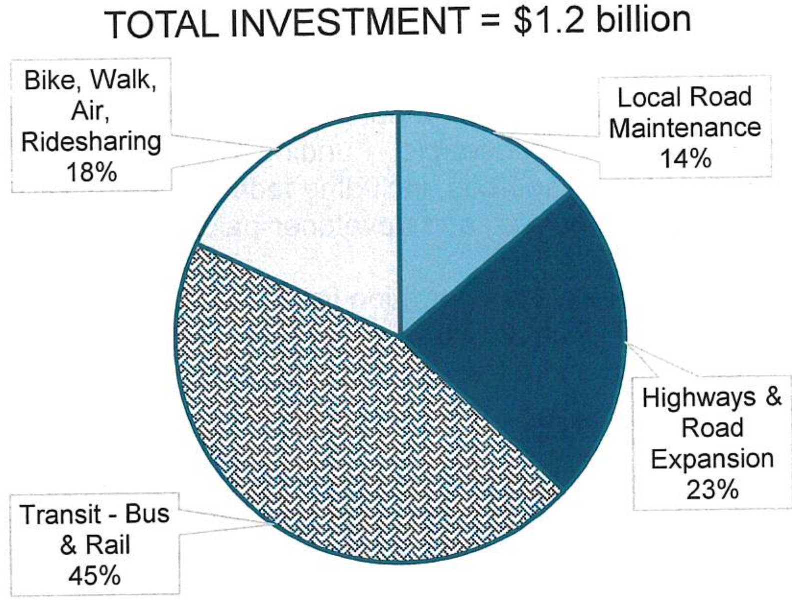
[18] City of Merced. (2013). City of Merced 2013 Bicycle Transportation Plan. https://www.cityofmerced.org/depts/cityclerk/boards_n_commissions/bicycle_advisory_commission/merced_bike_plan.asp

Figure 3: Summary of Expenditures by Mode 2014-2040



Source: MCAG Amended SCS (May 19, 2016).

Table 1 shows planned changes in transportation funding by mode between the 2014 SCS and the Amended SCS through 2040. The Amended SCS assumes that MCAG would receive an additional $300 million in funding, compared to the 2014 SCS. Of that additional funding, MCAG allocated an additional $200 million to Transit investments and an additional $100 million in Bike, Walk, Air, Ridesharing investments.

Table 1: A Comparison of Transportation Funding Assumptions by Mode through 2040

Transportation Mode	2014 SCS ($ millions)	Amended SCS ($ millions)
Local Road Maintenance	163	163
Highways & Road Expansion	272	272
Transit – Bus and Rail	326	**526**
Bike, Walk, Air, Ridesharing	110	**210**

Source: MCAG Amended SCS (May 19, 2016).

After the adoption of the Amended SCS, the region implemented a self-help taxation measure, Measure V, to help raise additional transportation revenue. Measure V, passed in November 2016, is a local ½ cent sales tax estimated to generate $15 million annually and $450 million over the 30-year life of the measure.[19] Funds generated by Measure V will allocate 44 percent to regional projects established in the RTP, 50 percent to local projects focused on needs of cities and Merced County and alternative modes projects that reduce single-occupant vehicle use, 5 percent to transit service improvements, and the remaining 1 percent to administrative needs.[20]

Supplemental Funding

In addition to federal, State, and local funding sources, Merced County has received funding for projects that are related to improving transit ridership, fostering walkable communities, and sustainable development. Between 2015-2016, Merced County was awarded over $360,000 in grant funding to provide free bus vouchers and promotional materials to increase transit ridership through the Low Carbon Transportation Program, one of 21 programs under the California Climate Investments.[21]

During 2015-2016, Caltrans awarded MCAG a Sustainable Transportation Planning Grant to support an update to the Short Range Transit Plan for Merced County-wide Transit.[22] That same year, the eight Valley MPOs and the University of California at Davis, Institute of Transportation Studies were awarded funding for a shared access pilot program to help address transit needs in rural areas.[23] During the 2016-2017 grant cycle, Merced County was awarded over $130,000 to develop the Walkable Winton Town Center Plan.[24]

Since 2010, the Strategic Growth Council (SGC) has awarded the City of Merced over $345,000 in grant funding for local planning efforts supporting transit-oriented development and climate action planning.[25] In addition, SGC awarded the eight Valley counties approximately $980,000 to implement the Sustainable Energy Roadmap, which will support municipal agencies in the Valley to adopt and pursue clean energy and sustainable development goals that optimize outcomes for their most

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[19] Merced County Association of Governments. (2016). Merced County ½ Cent Sales Tax Transportation Expenditure Plan Fact Sheet. https://www.mcagov.org/DocumentCenter/View/834/Measure-Fact-Sheet_rev-62716

[20] Merced County Association of Governments. (2016). Proposed 2016 ½ Cent Transportation Sales Tax Measure Expenditure Plan. http://www.mcagov.org/DocumentCenter/View/790

[21] California Air Resources Board. (2017). California Greenhouse Gas Reduction Fund Project Map. https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/auctionproceedsmap418.htm#

[22] Caltrans. (2016). Fiscal Year 2015-2016 Sustainable Transportation Planning Grant Awards. http://www.dot.ca.gov/hq/tpp/documents/AwardList.pdf

[23] Caltrans. (2016). Fiscal Year 2015-2016 Sustainable Transportation Planning Grant Awards. http://www.dot.ca.gov/hq/tpp/documents/AwardList.pdf

[24] Caltrans (2017). Fiscal Year 2016-2017 Sustainable Transportation Planning Grant Awards. http://www.dot.ca.gov/hq/tpp/grant_files/FY_16-17/16-17Awards.pdf

[25] Strategic Growth Council. (2017). Strategic Growth Council Project Viewer. http://sgc.apps.projects.databasin.org/v1/index.html

disadvantaged communities delivering a triple bottom line (environment, economy, and equity) benefit.[26] The objective of the roadmap is to reduce GHG emissions, protect open space and agricultural lands, increase water and energy conservation and efficiency, and promote a prosperous economy and safe, healthy, and walkable communities.

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26 California Natural Resources Agency. (2015). Bond Accountability – Project: Implementing a Sustainable Energy Roadmap for the San Joaquin Valley. http://bondaccountability.resources.ca.gov/Project.aspx?ProjectPK=12608&PropositionPK=4

II. 2014 SCS DEVELOPMENT

This section describes the planning context in which the SCS was developed and the process through which the plan was subsequently amended and adopted. MCAG began its public process in 2013 by consulting with various public and local agency representatives to gather input for alternative investment scenarios and to hold public workshops to explain the scenarios and provide opportunities to comment. These scenarios illustrated different options for the region's future through 2040.

A. Development and Selection of the SCS Scenario

In 2006, MCAG, along with the seven other Councils of Governments (COGs) in the Valley, initiated a long-range blueprint planning effort intended to establish a more sustainable vision for the region.[27] MCAG examined three scenarios ranging from a historical trend to a Blueprint scenario as the basis for their SCS scenario development process.

MCAG began the 2014 SCS planning process by updating its demographic and socioeconomic growth forecasts, to better understand the future needs of people who would live, work, and travel in the region (see APPENDIX A: CARB Technical Review for more information on the growth forecast). MCAG then developed an outreach plan and convened standing advisory committees, including a Citizen's Advisory Committee, Technical Planning Committee, and Technical Review Board. These advisory committees, local agencies and stakeholders, along with the MCAG Governing Board reviewed the transportation and land use tools, and development of the SCS alternative scenarios and results.

Between 2013 and 2014, MCAG hosted two rounds of public workshops on the SCS planning process. Based on the public and local jurisdiction input, regional priorities for growth and development were identified in three distinct scenarios. All of the scenarios met the 2020 target, but none of the scenarios met the 2035 target. The MCAG Governing Board decided select one of the scenarios and continue with adoption of the 2014 SCS, Federal Transportation Improvement Program, and Conformity Finding on September 25, 2014. After the adoption of the 2014 SCS, MCAG convened a Steering Committee to develop an Alternative Planning Scenario (APS) that would meet the targets. However, MCAG ultimately ended up preparing and adopting an Amended SCS to meet the targets.

B. Amended SCS

The Amended SCS scenario was based on an exchange of information with local agencies, the public, advisory committees. The Amended SCS scenario built off the

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[27] San Joaquin Valley Councils of Governments. (2010). San Joaquin Valley Blueprint Smart Growth Principles. http://www.valleyblueprint.org/smart-growth-principles.html

one of the alternative scenarios considered as part of the 2014 SCS process by adding more transportation and land use strategies.

Land Use and Transportation Characteristics of the Amended SCS

The Amended SCS scenario assumes 67 percent more dense growth than the historical pattern of growth in Merced County, and by 2035, projects that the share of multi-family housing units would increase by 98 percent compared with 2005. The result is a projected new density of 9 new residential housing units per acre.

Complementing the increases in average density assumed in the Amended SCS, the scenario also incorporates a higher level of investment in alternative modes, transportation demand management, transportation systems management, and other clean transportation strategies, including:

- Increased investment in expanding passenger rail and bus transit coverage and frequency including more frequent headways on bus transit, fare reductions, and express transit/bus rapid transit Investment in active transportation infrastructure
- Intelligent Transportation Strategies (ITS) and ramp metering
- Rideshare programs
- Electric vehicle subsidies and charger installations

MCAG's analysis estimates that the Amended SCS, if implemented, would achieve a 10.1 percent per capita GHG emissions reduction from passenger vehicles by 2020, and a 12.7 percent per capita reduction by 2035. The MCAG Governing Board certified the Amended SCS on May 19, 2016.

III. CARB STAFF EVALUATION

MCAG's quantification of GHG emissions reductions in the Amended SCS is central to its determination that the SCS would meet the targets established by CARB. Those targets for MCAG are 5 percent per capita reduction in 2020 and 10 percent per capita reduction in 2035 from 2005 levels. CARB staff's evaluation of MCTC's Amended SCS and technical documentation indicates that if implemented, the Amended SCS would meet the GHG emissions reduction targets set by the Board. This section describes the method CARB staff used to review MCTC's determination that its Amended SCS would meet its targets, and reports the results of CARB staff's evaluation of MCTC's quantification of the passenger vehicle GHG emissions reduction.

A. Methodology

CARB staff's evaluation of MCAG's Amended SCS included assessment of the technical aspects of regional modeling that underlie the quantification of GHG emissions reductions.

Government Code section 65080(b)(2)(J)(i) requires the MPO to submit a description to CARB of the technical methodology it intends to use to estimate GHG emissions from its SCS. MCAG's February 2014 technical methodology identifies the regional travel demand model, model inputs and assumptions, land use projections, growth forecast, performance indicators, and sensitivity analyses, as the technical foundation for its quantification.[28]

To assess the technical soundness and general acceptability of MCAG's GHG emissions quantification, four central components were evaluated: 1) data inputs and assumptions, 2) modeling tools, 3) model sensitivity, and 4) performance indicators. The general method of review is outlined in CARB's July 2011 document entitled *Description of Methodology for ARB Staff Review of Greenhouse Gas Reductions from Sustainable Communities Strategies Pursuant to SB 375*. To address the unique characteristics of each MPO region and modeling system, CARB's methodology is tailored for the evaluation of each MPO.

For MCAG, CARB staff's evaluation examined how MCAG's travel model operates and performs when estimating travel demand, land use impacts, and future growth, and how well it is able to quantify GHG emissions reductions associated with the SCS. In evaluating whether the modeling was reasonably sensitive for these purposes, CARB staff examined how well MCAG's travel demand model responded to specific changes in input values, as well as how accurately it replicated observed results.

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[28] San Joaquin Valley Regional Planning Agencies' Directors Committee. (14 February 2014). San Joaquin Valley GHG Quantification Technical Methodology. https://www.arb.ca.gov/cc/sb375/joint_sjv_tech_methodology.pdf

CARB staff used publicly available information in MCAG's Amended SCS and accompanying documentation, including the technical appendices, model documentation, technical memo with amendment changes, and data table for its evaluation (see APPENDIX B. MCAG Modeling Data Table).

B. Data Inputs and Assumptions

CARB staff reviewed MCAG's key modeling inputs and assumptions for land use, forecasted regional growth, the region's transportation network, as well as travel cost, including the adjustments MCAG made as part of their Amended SCS. CARB found the sources and processing of the input data and assumptions were reasonable. More detail on the individual data input and assumptions reviewed by CARB staff can be found in APPENDIX A: CARB Technical Review.

C. Modeling Tools

Similar to other California MPOs, MCAG utilized a land use scenario planning tool, a regional travel demand model (also known as the Three-County Model[29]), and CARB's EMFAC model to quantify base and future year VMT and GHG emissions for their Amended SCS. Specifically, MCAG used the Envision Tomorrow land use tool to develop the base and future year land use scenarios, allocating regional growth according to the desired criteria and priorities of each scenario (e.g., residential density, transit service). MCAG then input the zonal land use and demographic data into the regional travel model to quantify VMT for each planning scenario. In the last step of the GHG emissions quantification process, MCAG input the VMT estimates from the travel model into the EMFAC 2011 emissions model to estimate GHG emissions of its 2014 Amended SCS. CARB found MCAG's GHG emissions modeling process to be consistent with common practice.

CARB staff also reviewed the sensitivity, or responsiveness of MCAG's regional travel model to changes in key modeling or SCS strategy variables, including: auto operating cost, household income distribution, transit frequency, residential density, and proximity to transit. For all sensitivity tests, MCAG provided CARB the model outputs of VMT, number of person trips, and mode share,[30] and CARB staff assessed the modeled

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[29] In 2010, the eight MPOs in the Valley began a collaborative process to improve their travel demand modeling capabilities. This process, known as the San Joaquin Valley Model Improvement Plan (MIP) was funded by the Strategic Growth Council (SGC) and was completed in 2012. The MIP effort substantially upgraded and standardized travel demand models of the Valley MPOs and improved on their ability to evaluate land use and transportation strategies pertinent to meeting SB 375 requirements. In 2013, MCAG together with the San Joaquin Council of Governments and Stanislaus Council of Governments further updated the MIP model to reflect model base year (2008) conditions of their regions. The resulting model, covering all three counties, is known as the Three-County Model. The Amended SCS is MCAG's first SCS to be developed using the Three-County Model.

[30] For particular sensitivity tests, MCAG provided additional model outputs such vehicle ownership by household size, transit ridership.

change of direction and magnitude based on the empirical literature. CARB found MCAG's model sensitivity to be reasonable based on the consistent response of VMT in directionality and/or magnitude to the tested variables as compared to the empirical literature. More detailed discussion on the modeling tools, MCAG's application of the tools, associated sensitivity testing scenarios and results, and CARB staff's recommendations for model improvement can be found in APPENDIX A: CARB Technical Review.

D. Off-Model Calculations

MCAG incorporated into its Amended SCS potential GHG emissions reductions from strategies that could not be reflected in the travel demand model. These strategies include enhanced transit, active transportation, rideshare, intelligent transportation strategies (ITS) and ramp metering, passenger rail expansion, and enhanced electric vehicle penetration. Table 2 further breaks down the GHG benefits by strategy. CARB staff reviewed MCAG's assumptions and calculations for each strategy and found them to be reasonable, and consistent with findings from the available literature on the potential GHG benefits from these off-model strategies. Further information on the description of each off-model strategy and the associated assumptions used in estimation of GHG benefits can be found in APPENDIX A: CARB Technical Review and APPENDIX C: MCAG SCS Off-Model Strategy Quantification Methodology.

Table 2: Off-Model Strategies

Off-Model Strategy	Percent GHG Emissions Reduction in 2035
Enhanced Transit	-0.6%
Active Transportation	-0.4%
ITS and Ramp Metering	-0.4%
Rideshare	-1.6%
Passenger Rail Expansion	-0.3%
Enhanced Electric Vehicle Penetration	-0.4%
Total	**-3.7%**

Source: MCAG SCS Off-Model Strategy Quantification Methodology.

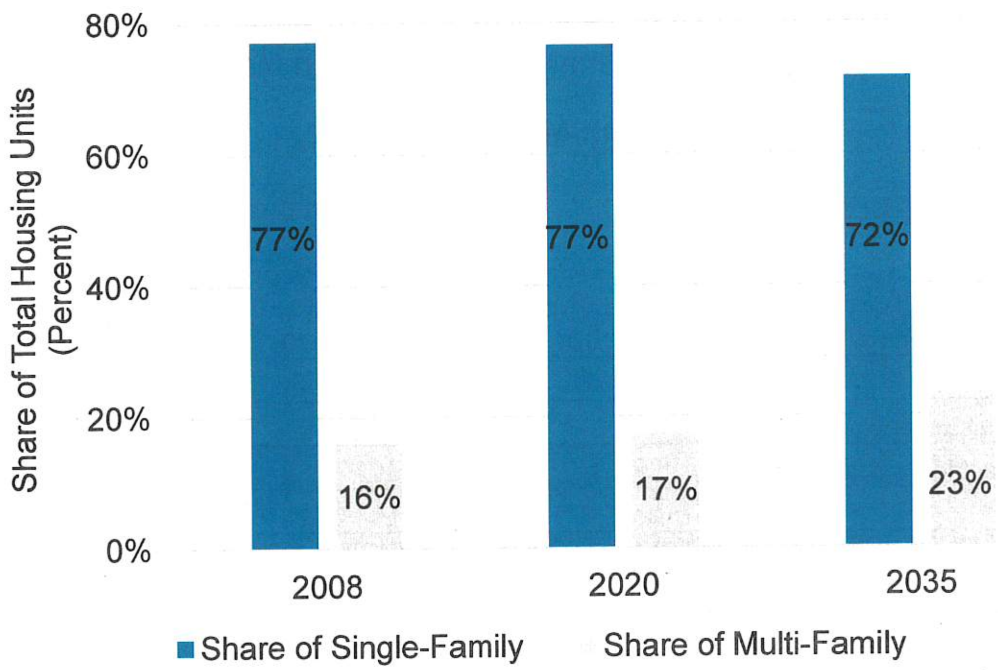
E. SCS Performance Indicators

CARB staff's evaluation identified changes in important land use and transportation-related indicators that describe SCS performance. These indicators are examined to determine if they can provide quantitative and qualitative evidence that the SCS, if implemented, could meet its GHG targets. The evaluation looked at directional consistency of the indicators with MCAG's modeled GHG emissions reductions, as well as the general relationships between those indicators and GHG emissions reductions based on the empirical literature as discussed in the CARB-funded policy briefs and corresponding technical background documents.[31] CARB staff evaluated the following SCS performance indicators: mix of housing types and per capita passenger VMT. CARB staff found the indicators to be directionally supportive of MCAG's claimed emissions reductions when looking at MCAG projected trends relative to denser housing development and regional VMT. These indicators are based on information provided by MCAG in APPENDIX B: MCAG Modeling Data Table.

Mix of Housing Types

Housing type mix influences the land use patterns that can be achieved in a region. The greater the proportion of housing growth that is multi-family and small-lot size housing types, the more opportunity a region has to accommodate future growth through a more compact land use pattern. Figure 4 displays the share of total housing units by housing type projected in the Amended SCS. Compared to model base year of 2008, the share of single-family housing will decrease by 5 percent, while the share of multi-family housing will increase by 6 percent by 2035.

Figure 4. Share of Total Housing Units by Housing Type



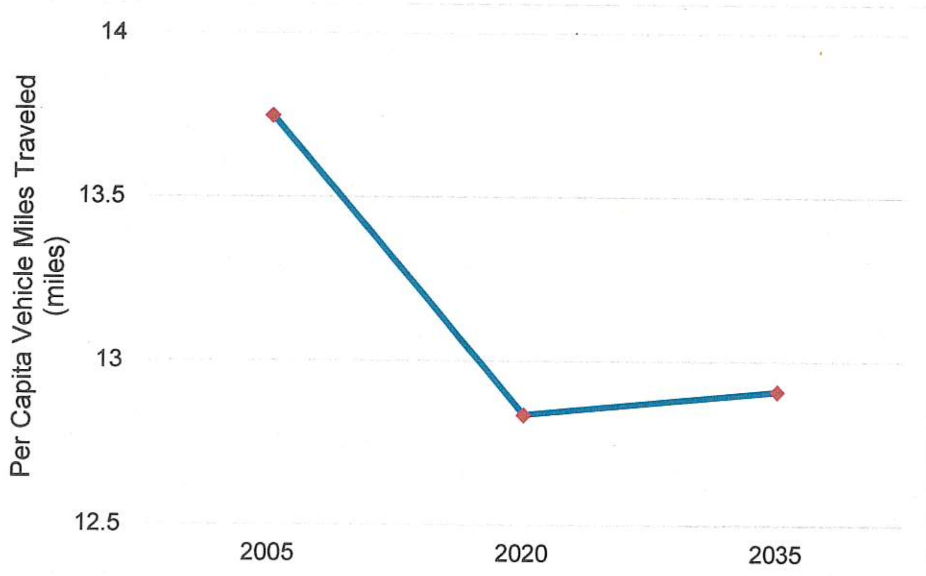
Source: APPENDIX B. MCAG Modeling Data Table.

[31] The policy briefs and technical background documents identify the impacts of key transportation and land use policies on vehicle use and GHG emissions based on the scientific literature and can be found at http://arb.ca.gov/cc/sb375/policies/policies.htm

Vehicle Miles Traveled (Per capita passenger VMT)

The Amended SCS shows a decline in per capita passenger vehicle VMT between 2005 and 2035. As shown in Figure 5, per capita VMT decreases by 6.7 percent between 2005 and 2020, and by 6.1 percent between 2005 and 2035. The reported statistics show that the average number of vehicle trips per person per weekday for all trip purposes in the MCAG region would be reduced from 2005 to 2035 consistently. CARB staff note that VMT per capita between 2020 and 2035 appears to increase, however, given that MCAG's Amended SCS includes off-model strategies that are expected to reduce VMT per capita and are not reflected in these figures, CARB staff found the indicator to be directionally supportive of MCAG's claimed emissions reductions.

Figure 5: Per Capita Passenger VMT



Source: APPENDIX B. MCAG Modeling Data Table.

IV. CONCLUSION

A. Findings

Based on CARB staff's independent assessment, MCAG's SCS, if implemented, would meet the targets and yield a minimum per capita GHG emissions reduction of 5 percent in 2020 and 10 percent in 2035 compared with 2005 levels.

B. Recommendations

Improvements are realized with each iteration of a region's SCS. CARB staff have included a summary of the following recommendations for MCAG to improve their second round SCS development.

Future SCS Strategy Tracking and Reporting

- For all strategies MCAG quantified for SB 375 credit, begin tracking on the ground, region-specific data related to performance, including: 1) the types and timing of local and regional planning and development activity and its relationship to implementation of the region's SCS strategies; and 2) the types and timing of local and regional transportation project investments and their relationship to implementation of the region's SCS strategies.

General SB 375 Emissions Benefit Calculations

- Refine inputs, assumptions, and methodology for quantifying benefits of included off-model strategies in consultation with CARB staff to ensure that benefits reflect local conditions and data, and that any outside study data being used is appropriately applied.
- Track and exclude group quarters population when calculating per capita CO_2 emissions for SB 375 target demonstration.

Future Model Updates to Improve Sensitivity to SCS Strategies

- Use the latest available household travel survey data and transportation network data to reflect existing conditions of the region.
- Use the latest available independent data sources such as the National Household Travel Survey (NHTS), Census Transportation Planning Package (CTPP), traffic counts, and the American Community Survey (ACS) to validate the travel model.
- Gather more recent traffic count data at different facility types, with large enough sample sizes for model validation purposes.

- Include costs such as tire and maintenance costs in estimating auto operating cost.
- Increase sensitivity to transit trips by coding transit routes and stops on a GIS-based layer, and include bike and pedestrian facilities (e.g., bike paths, bike lanes) in the transit network to reflect walk- or bike-access to transit stations.
- Validate the vehicle ownership module with latest vehicle registration data from the Department of Motor Vehicles' (DMV).
- Include sensitivity to land-use mix, particularly in areas with high transit use.
- Develop a nested logit-based mode choice module to improve sensitivity of changes to different means of transportation.
- Include demographic and socioeconomic characteristics in the mode choice module.
- Document the model estimation process, estimated parameters, and statistical significance of the estimates for all model components.

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APPENDIX A: CARB Technical Review

CARB's technical review of MCAG's tools and GHG emissions quantification for base year and SB 375 analysis years focused on the model inputs and assumptions, application of modeling tools, and modeling results. CARB staff also reviewed the reported data and information associated with MCAG's off-model strategies, and the results of model sensitivity tests of auto operating cost, household income distribution, transit frequency, residential density, and proximity to transit. MCAG used a regional travel demand model to quantify the amount of travel in the region, which was consistent with the structure and operation of other Valley MPOs' travel models. The following are details of CARB's findings on each aspect of the technical review of MCAG's quantification.

I. Data Inputs and Assumptions

MCAG's key travel model inputs and assumptions were evaluated to confirm that model inputs represent current and reliable data, and were used appropriately. Specifically, a subset of the most relevant model inputs were reviewed, including: 1) regional socioeconomic characteristics, 2) the region's transportation network inputs and assumptions, and 3) cost assumptions. In evaluating these three input types, CARB staff reviewed the assumptions MCAG used to forecast growth and VMT, and compared model inputs with underlying data sources. This involved using publicly available and authoritative sources of information, such as national and statewide survey data on socioeconomic and travel factors, as well as region-specific forecasting documentation.

A. Growth Forecast and Land Use Assumptions

Demographic data and forecasts describe a number of key characteristics used in TDMs. The regional growth forecast describes how many people will live in the region, how many jobs the region will have, and the anticipated number of households.

Similar to the other Valley MPOs, demographic forecasts for population, employment, and households were prepared by The Planning Center. The Planning Center's March 2012 report, *San Joaquin Valley: Demographic Forecasts 2010 to 2050*, cites data sources including the United States Census Bureau, the California Department of Finance (DOF), and the California Employment Development Department (EDD). MCAG used the Planning Center forecast as Countywide control values and then disaggregated the information to the local level with input from its local agencies. MCAG's growth forecast is summarized in Table 3. The demographic forecasts were unchanged between the 2014 SCS and the Amended SCS. The population of the MCAG region is forecast to grow from about 256,000 in 2010 to 383,000 in 2035. The number of households in the MCAG region grows by more than 36,000 between 2010 and 2035. Additionally, employment grows by about 20,000 between 2010 and 2035.

Table 3: Demographic Forecast (2010-2035)

	Population*	Households	Employment*
2010	255,793	75,642**	66,000
2020	302,972	90,047***	74,293
2035	383,397	112,389***	86,732

Source: * MCAG Amended SCS (May 19, 2016).
** United States Census Bureau. (2010). Profile of General Population and Housing Characteristics: DP-1.
***MCAG SCS Data Table, Appendix B.

Housing Units and Households

Housing units were estimated based on the general plans of the cities and Merced County. Local jurisdictions provided potential housing growth by transportation analysis zone (TAZ). MCAG then corroborated potential housing growth by TAZ with expected growth totals. The number of households is projected to increase by almost 36,000 between 2010 and 2035, yielding an annual growth rate in households of about 2 percent.

Employment

Employment projections in the Amended SCS were developed as part of the socioeconomic profile in the MCAG travel model. Employment in the MCAG region is forecast to increase by almost 21,000 jobs between 2010 and 2035, yielding an annual employment growth rate of about 1 percent. Which means job growth is slowly increasing in the region.

Land Use Assumptions

There are seven local jurisdictions in the MCAG region (six cities and Merced County) that adopt unique comprehensive land use plans commonly known as general plans. Current land use was simulated through GIS, but future land use was not mapped. Future land use assumptions used by MCAG were provided by the local jurisdictions, in the form of assumed housing growth by TAZ.

MCAG region's cities of Merced, Los Banos, Dos Palos, Livingston, Gustine, and Atwater, have adopted general plan land use and housing goals. The Amended SCS assumed a more compact development pattern, 67 percent more dense than the historical pattern of development.

B. Transportation Network Inputs and Assumptions

The transportation network is a map-based representation of the transportation system serving the MCAG region. One part of the transportation network is the roadway network, which consists of an inventory of the existing roadway system, and link-level travel times and distances. The other part of the transportation network is the transit network, which contains data such as route name, stop locations, transit fares, headway, and type of transit service. The transportation network includes roadway and transit networks for both the model base year of 2008 and for future analysis years (i.e., 2020, 2035). CARB staff reviewed the transportation network, and network assumptions such as link capacity and free-flow speeds. The methodologies MCAG used to develop the transportation network and travel model input assumptions is consistent with guidelines given in the National Cooperative Highway Research Program (NCHRP) Report 716.

Roadway Network

The roadway network in the Three-County Model is a representation of the automobile roadway system, which includes freeway, highway, expressway, arterial, collector, local and freeway ramps in the region. The roadway network provides the basis of estimating zone-to-zone travel times and costs (in terms of travel distance and travel time) for the trip distribution and mode choice steps of the modeling process, and for trip routing in vehicle assignments.

Table 4 summarizes the reported roadway lane miles in the MCAG region in 2005 by facility type. These facility type classifications are consistent with the Federal Function Highway Classification system. Link attributes (e.g., route/street name, distance, capacity, speed) are coded for each roadway segment, which are consistent with common practice.

Table 4: Lane Miles in 2005 by Facility Type

Facility Type	Lane miles in 2005
Freeway	675
Arterial	1,482
Collector	556
Local	326

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Link Capacity and Free Flow Speed

Link capacity is defined as the number of vehicles that can pass a point of roadway at free-flow speed in an hour. One important reason for using link capacity as an input to the Three-County Model is for congestion impact, which can be estimated as the additional vehicle-hours of delay base on the 2010 Highway Capacity Manual (2010 HCM).[32] Table 5 summarizes the default link capacity assumptions used in the Three-County Model. The capacity of each road segment in the network is based on the terrain, facility type, and area type, and is determined using the methodology suggested in the 2010 HCM.

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[32] Transportation Research Board. Highway Capacity Manual. Washington D.C.: 2010. National Research Council.

Free-flow speed is used to estimate the shortest travel time between origin and destination zone in the highway network. Factors such as prevailing traffic volume on the link, posted speed limits, adjacent land use activity, functional classification of the street, type of intersection control, and spacing of intersection controls can affect link speed. The Three-County Model estimated the free-flow speed of each link segment (Table 5) using the Bureau of Public Roads formulas suggested in the 2010 HCM.

Table 5. Default Link Capacity and Speed Assumptions by Terrain Type

Facility Type	Terrain					
	Flat		Rolling		Mountain	
	Speed	Capacity	Speed	Capacity	Speed	Capacity
Freeway	55 to 70	1,750 to 2,100	65 to 70	1,580 to 1,800	65	1,310 to 1,500
Highway	40 to 45	1,300 to 1,680	40 to 45	1,060 to 1,300	40 to 45	570 to 700
Expressway	40 to 55	800 to 1,155	50 to 65	650 to 1,300	40 to 55	350 to 700
Arterial	25 to 45	750 to 945	30 to 45	610 to 1,300	30 to 45	330 to 700
Collector	35 to 50	700 to 735	50	570 to 1,300	25 to 40	310 to 700
Local	25 to 40	600	50	550 to 1,000	25 to 40	330 to 600
Ramps	45 to 50	1,250 to 1,900	45 to 50	1,250 to 1,800	35 to 50	1,250 to 1,500

Source: Fehr & Peers (2014). Three-County Model Description.

CARB staff reviewed the methodology used in estimating highway free-flow speeds in the MCAG region. The Three-County Model's assumption of free-flow speed is consistent with the recommended practice indicated in the NCHRP Report 716.

Transit Network

The transportation network of the Three-County Model also includes a transit network. The transit network was developed using the completed roadway network, to which transit routes and stops information was added. The purpose of developing a transit network are: verification of access links and transfer points, performance of system level checks on frequency and proximity between home and transit station or stop, and relating transit speeds to highway speeds.

Elements coded in the transit network include walk/bike access to transit, drive access to transit, park-and-ride lots, highway based (i.e., bus) and non-highway based (i.e., rail) transit in the study area. Some attributes coded in the transit network include transit fare, travel time, park-and-ride locations, and maximum distance for walk and ride to transit stops. MCAG estimated transit bus travel times from the highway network, with a delay factor to account for stops and slow operating speeds. The Three-County Model assumes a walking speed of three miles per hour for walk access in estimating transit travel time. The three counties derived bus travel time from the roadway network including a delay factor to account for stops and slower operating speeds. The three counties also agreed to set the maximum wait time between buses at transfer location to be five minutes rather than one-half the headway.

CARB staff reviewed the methodology MCAG used in developing its transit network and found consistent with the procedures discussed in the NCHRP Report 716 and *Travel Model Validation and Reasonableness Checking Manual* by the Federal Highway

Administration (FHWA). In future model updates, MCAG should consider coding transit routes and stops on a GIS-based layer, and include bike and pedestrian facilities (e.g., bike paths, bike lanes) in the transit network to reflect walk- or bike-access to transit stations, which may increase the model's sensitivity to transit trips. Additionally, MCAG should consider including more details of transit related attributes such as operational miles of local bus, transit fares assumptions, and bike and pedestrian lane miles in the model documentation, especially if the region considers promoting alternative transportation.

C. Cost Inputs and Assumptions

Travel cost is one of the major factors determining the mode of transportation for any given trip. CARB staff reviewed basic travel cost components, such as auto operating cost and value of time, that were used as inputs in the Three-County Model. To examine the responsiveness of the Three-County Model to changes in the cost variable or other model inputs, MCAG performed model sensitivity tests for auto operating cost and transit frequency. The results of the sensitivity tests are presented in the model sensitivity analysis section of this report.

Auto Operating Cost

Auto operating cost is a key parameter used in the mode choice step of the Three-County Model. MCAG defined auto operating cost solely based on cost of fuel. The price of fuel is the amount consumers pay at the pump for regular grade gasoline (in dollars/gallon). When gasoline prices go up, drivers are expected to decrease their frequency of driving, reduce their travel distance, increase their use of public transit, and/or switch to more fuel efficient cars. Lower gas prices would be expected to increase VMT.

MCAG forecasted fuel price in 2020 and 2035 using the historical trend from 1998 to 2008. The corresponding auto operating costs were then derived by dividing the fuel price of the year by fuel efficiency assumptions. Table 6 summarizes the auto operating cost assumptions used in the Three-County Model.

Table 6: Auto Operating Cost (cents/mile, in 2000 Dollars)

	2008	2020	2035
Auto Operating Cost	0.19	0.22	0.24

Source: Fehr & Peers (2014). Three-County Model Description.

Although fuel cost is the major component of travel cost for autos, other costs such as the cost of vehicle maintenance and tire replacement should also be considered. CARB staff recommends MCAG include these additional costs when estimating auto operating cost for its future travel model update.

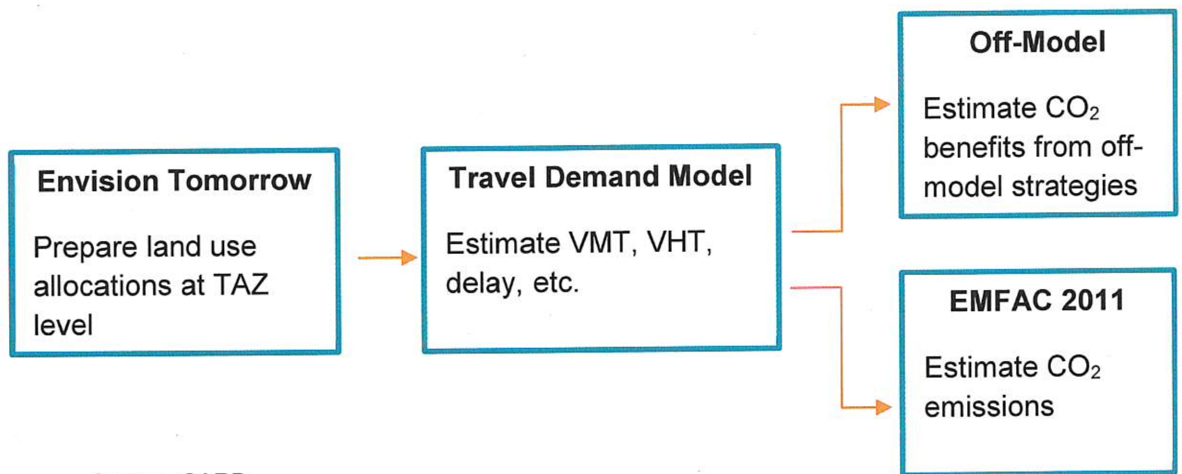
Cost of Time

A value of time assumption is used in the trip distribution step to estimate the travel cost of alternative routes. MCAG converted travel cost to cost of time using a value of time. The average perceived value of time that MCAG used is similar to that used by other MPOs in the Valley, at six dollars per hour per person. The value of time was also further adjusted according to vehicle ownership status.

II. Modeling Tools

Similar to other Valley MPOs, MCAG used the Envision Tomorrow™ land use scenario planning tool, a trip-based travel demand model, and the CARB vehicle emission model (EMFAC2011) to quantify the GHG emissions for the Amended SCS (Figure 6). The analysis years for the GHG emissions were 2005, 2020, and 2035. Figure 6 shows the flow chart of the modeling process. MCAG collected demographic data (e.g., population, housing units) and future socioeconomic demands from local jurisdictions, and used Envision Tomorrow™ to prepare land use allocations at the Transportation Analysis Zone (TAZ) level as inputs for the travel model to estimate the amount of travel in the MCAG region. Results from the travel model, such as VMT by time of day and vehicle hours of travel (VHT), were input into EMFAC 2011 to estimate GHG emissions associated with the Amended SCS.

Figure 6: MCAG's Modeling Tools



Source: CARB.

A. Land Use Planning Tool

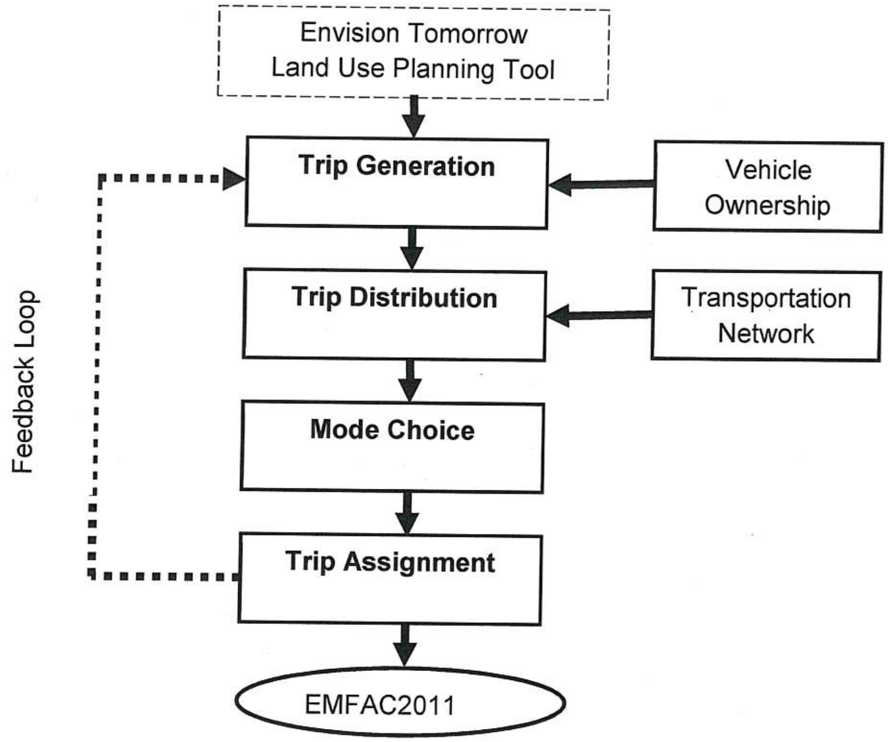
MCAG used the Envision Tomorrow™ land use allocation tool to allocate growth and demographics into geographic areas within the region according to specific requirements of each planning scenario. Land use modeling results and calculation elements associated with a scenario are stored in look-up table and GIS-map based files. Different land use scenarios based on different policies were then developed for evaluation and comparison purposes. The spreadsheet formatted outputs associated with MCAG's preferred scenario served as inputs to the travel demand model.

B. Travel Demand Model

Similar to most regional travel demand models, the Three-County Model is a four-step model that includes trip generation, trip distribution, mode choice, and trip assignment

(Figure 7). The travel model uses land use, socioeconomic, and transportation network data to estimate travel patterns, roadway traffic volumes and transit volumes. The model contains approximately 6,600 transportation analysis zones (TAZs) representing origins and destinations of travel in the model area. Travel to/from and through the model area is represented by 100 gateway zones at major road crossings of the county line for an interregional travel estimate.

Figure 7: The Three-County Travel Demand Model



Source: CARB.

Vehicle Ownership

Similar to the other Valley MPOs, modeling of vehicle ownership is a new component of the Three-County Model. The vehicle ownership module calculates the number of motor vehicles in the MCAG region based on demographic characteristics, auto operating cost, and accessibility, which helps to capture the economic characteristics of each household. The output of this component is a critical input to the trip generation step, accounting for travelers' long-term decisions for mode of transportation.

CARB staff recommends that MCAG more thoroughly document the development process and application of the travel model's vehicle ownership component in the next model update. This will assist CARB staff in assessing the outputs. For future model improvements, MCAG should consider validating the vehicle ownership module with the latest vehicle registration data from the Department of Motor Vehicles' (DMV).

Trip Generation

Trip generation, the first step of travel demand modeling, quantifies the amount of travel in terms of person-trips in a model area. This module of the Three-County Model estimates person-trips by trip purpose using cross-classification based on residential data, employment information, and school enrollment from the 2000/2001 California Household Travel Survey (CHTS) and is supplemented by information from previously developed models. There are 11 trip purposes contained in this module to capture travel activities in the region, including: home-based work (HBW), home-based shopping (HBShop), home-based K12 (HBK12), home-based college (HBCollege), home-based other (HBO), work-based other (WBO), other-based other (OBO), highway commercial, trucks-small, trucks-medium, and trucks-large.

Consistent with any conventional trip-based travel demand model, the Three-County Model has two trip ends, trip production[33] and trip attraction.[34] The trip production rates for HBW trips by housing type and by auto ownership, and for WBO trips by employment type were derived from survey results from the 2000/2001 CHTS. The Three-County Model also used survey results from all eight counties in the Valley to ensure larger sample sizes. HBW trip attraction rates were also derived from the 2000/2001 CHTS because the survey has records of surveyed households and their employment information. Table 7 summarizes the trip production and attraction rates by trip purpose. The differences between estimated trip production and attraction were within the 10 percent difference stated in the 2010 FHWA's Travel Model Validation and Reasonable Checking Manual, except for HBW trips, which were within 15 percent. Based on reviews of other Valley MPOs' SCSs, CARB staff understand that the greater difference in HBW trips is due to limited sample sizes for Valley counties from the 2000/2001 CHTS. CARB staff recommends MCAG update the Three-County Model with latest available household travel survey data for the next model update.

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[33] Trip production is defined as the home end of any home-based trip, regardless of whether the trip is directed to or from home. If neither end of the trip is a home, it is defined as the origin end.
[34] Trip attraction is defined as the non-home end of a home-based trip. If neither end of the trip is a home, the trip attraction is defined as the destination end.

Table 7: Trip Productions and Attractions

Trip Purpose	Productions	Attractions	Percent Difference	FHWA Criterion
HBW	510,513	587,396	15%	±10%
HBSchool*	294,572	296,142	1%	±10%
HBO	1,135,038	1,173,813	3%	±10%
NHB	719,092	740,799	3%	±10%
Total	2,659,215	2,798,150	5%	±10%

Source: Fehr & Peers (2014). Three-County Model Description.
*HBSchool is an aggregation of HBK12 and HBCollege.

The OBO trip production and attraction rates for each employment type were estimated by comparing the trip generation derived from the 2000/2001 CHTS to standard vehicle trips in the Institute of Transportation Engineers (ITE) Trip Generation manual. The modeled person trip rates were then converted to vehicle trips using average auto occupancies for the three counties for each trip purpose (i.e., drive alone, shared ride 2, shared ride 3+), which is consistent with common modeling practice.[35]

As part of the evaluation of the trip generation module, CARB staff reviewed the variables used in the trip production and attraction models, and the relationship of trip rates to key variables in the model. Overall, the trip generation module is consistent with the process for estimating person trips outlined in NCHRP Report 716. As part of future model improvement, MCAG should consider including some sensitivity to land-use mix, particularly in areas with high transit use to capture the transit-oriented development travel behavior. CARB staff recommends MCAG use the latest available independent data sources such as the National Household Travel Survey (NHTS), Census Transportation Planning Package (CTPP), and the American Community Survey (ACS) to validate the trip generation module given the limited survey samples from CHTS.

Trip Distribution

The trip distribution is the second module of the Three-County Model, which utilizes a gravity model[36] to estimate how many trips travel from one zone to any other zone. The inputs to the gravity model include the person trip productions and attractions for each zone, zone-to-zone travel cost, and friction factors[37] that define the effect of travel time. The travel time between a pair of zones is based on the shortest path connecting the two zones. The results of the zone-to-zone travel times serve as input to the trip

[35] Shared ride 3+ includes vehicles with 3 or more riders including driver in the vehicle, calculated as 3.5 persons per vehicle.
[36] A gravity model assumes that urban places will attract travel in direct proportion to their size in terms of population and employment, and in inverse proportion to travel distance.
[37] Friction factors represent the effect that travel time exerts on the propensity for making a trip to a given zone.

distribution process. Intrazonal travel times were assumed to be 100 percent of the average travel time to the nearest adjacent urban TAZ and one-third the average travel time to the nearest adjacent rural TAZ.

Because time is an important factor in trip distribution, the Three-County Model added terminal times[38] to reflect the average time to access one's vehicle at the each end of the trip. The three counties agreed to use a terminal time of one minute for all TAZs in the model area of the Three-County Model.

In evaluating the trip distribution module of the Three-County Model, the average travel time by trip purpose was reviewed. Table 8 shows the average travel time by trip purpose from the model. The differences between the modeled travel time and the observed travel time (CHTS) are due to the limited samples from the 2000/2001 CHTS for the three counties, the time gap between model base year (i.e., 2008) and survey year, and also due to the different survey information collection locations in California which could vary from the three counties' demographic make-up.

Table 8: Average Travel Time by Trip Purpose (Minutes)

Trip Purpose	Model	CHTS
HBW	14.9	21.5
HBO	23.8	15
NHB	15.1	14.4

Source: Fehr & Peers (2014). Three-County Model Description.

To better estimate the GHG emission reductions associated with SCS strategies in the future, CARB staff recommends that MCAG consider developing a destination choice model, which can improve the sensitivity of changes to land use and socioeconomic factors on trip distribution by better reflecting the attributes that influence a person's decision to travel. Additionally, MCAG should provide goodness-of-fit statistics in future model documentation and the frequency distribution of trip lengths to evaluate the performance of the trip distribution module.

Mode Choice

The mode choice module of the Three-County Model uses demographics, travel cost and time from trip distribution outputs, and average ratios of persons to vehicle from travel surveys to assign person-trips by means of transportation. The Three-County Model uses a multinomial logit model[39] in the mode choice module to assign the person-trips to mode of drive-alone, shared ride 2 people, shared ride 3+ people, walk

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38 The three counties estimated terminal time by taking the difference between the model estimate of roadway network travel time and the reported travel times for trips in the three counties from the 2000/2001 CHTS.

39 A multinomial logit model assigns the probability of using a particular mode based on an attractiveness measure or utility for an alternative mode in relation to the sum of the attractiveness measures for all modes.

to transit, drive to transit, bicycle, or walk. For the transit modes, the model further distinguishes between walk- and drive-access. The mode choice module estimates for the 2008 base year were calibrated using the 2000/2001 CHTS survey data. Table 9 shows the calibrated percent mode share in the model base year for the model area. Mode share estimates were compared against the observed data from CHTS. The differences between model estimates and observed data were expected due to the time gap between the model base year and the time of the survey. Due to the rural geography and agricultural nature of the region, significant commuter trips by carpool and vanpool are assumed in the three counties, especially for farmers, and residents who work outside the region, which supports the lower share of SOV and higher share of HOV compared to CHTS results.

Table 9: Person-trips by Mode in 2008

Mode	Model	CHTS
SOV	41.0%	51.9%
HOV	49.7%	44.1%
Transit	1.5%	0.5%
Bike and walk	7.8%	3.4%

Source: Fehr & Peers (2014). Three-County Model Description.

The method used to develop the mode choice module is consistent with the approaches used nationwide as cited in NCHRP Report 716. However, the coefficients and constants used in the module are based on other regional models. In future model updates, the three counties should consider developing a nested logit based mode choice module since they have more than two mode choices. The mode choice module should consider including demographic and socioeconomic characteristics in allocating the trips between modes. Model documentation should consider including more details on the estimation process, estimated variables, and statistical significance of the estimates.

Trip Assignment

In the trip assignment module, vehicle trips from one zone to another are assigned to specific travel routes between the zones in the transportation network. Congested travel information serves as feedback to the beginning of the process until convergence is reached. This process utilizes a user equilibrium assignment concept to assign vehicles to roadways in the network. The iteration runs until no driver can shift to an alternative route with a faster travel time. The convergence criteria used in the Three-County Model is 0.001 relative gap,[40] or a maximum internal iteration of 20 iterations for peak and off-peak period traffic assignments and 50 iterations for peak hour traffic assignments. The Three-County Model used the Bureau of Public Roads

[40] Relative gap measures the relative difference of traffic flow between current iteration and the previous iterations.

(BRP) formula to estimate congested travel time, which is a common practice among transportation planning agencies.

For transit trip assignment, the best path was chosen based on in-vehicle time plus weighted out-of-vehicle times. Transit trips were assigned in four groups: peak period, walk access; peak period, drive access; off-peak, walk access; and off-peak, drive access.

After the initial trip distribution and assignment using free-flow speed on the roadway network, the congested travel time from the most recent A.M. peak three-hour period is used as input to the HBW trip distribution, and the congested travel times from the most recent off-peak traffic assignment are used for the other trip purposes. However, the Three-County Model was not calibrated with a feedback mechanism for each step, which is recommended to be included in the next model update.

In evaluating the trip assignment module, CARB staff reviewed the assignment function used in the model, and the estimated and observed volume counts by facility type as shown in Table 10. CARB staff also compared these estimated volume counts by facility type with observed data in the region. The travel model uses an assignment function as required by CTC's *2010 California RTP Guidelines* to estimate the link volumes and speeds. The coefficients used in the assignment function were consistent with FHWA guidelines. Comparison of estimated and observed traffic counts at the screenline[41] locations by facility type in Table 10 shows that the differences did not fall within the recommended range of FHWA guidelines. This large difference can be attributed to the lack of data points from certain facility types (e.g. freeway, expressway), as well as the reported modeled and/or count data being out-of-date. Between now and the next model update, MCAG should consider gathering more recent traffic count data at different facility types and making sure there are large enough sample sizes.

Table 10: Estimated and Observed Traffic Counts for MCAG Region

Facility Type	Model Estimate	Traffic Count	Percent Difference	FHWA Guidelines
Freeway	779,805	472,169	65%	±7%
Expressway	5,992	3,059	96%	±15%
Arterial	0	0	N/A	±15%
Collector	0	0	N/A	±25%

Source: Fehr & Peers (2014). Three-County Model Description.

The estimated VMT from the Three-County Model for the MCAG region and the observed data from the Caltrans Highway Performance Monitoring System (HPMS)[42]

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41 The screenline is an imaginary line used to split the study area into different parts. Along these lines, traffic counts are collected to compare against the model estimates.

42 Highway Performance Monitoring System is a federally mandated program to collect roadway usage statistics for essentially all public roads in the US.

were compared at the county level (Table 11). The difference was within one percent, which is within MCAG's evaluation criteria of +/- 3 percent.

Table 11: Model Validation - VMT for MCAG Region

	Model	HPMS	Percent Difference
VMT	7,048,072	6,975,375	1%

Source: Fehr & Peers (2014). Three-County Model Description.

Model Validation

Model validation, generally the last step in the development of any regional travel demand model, reflects how well the model estimates match with observed data that were not used in model development and/or calibration. The California Transportation Commission (CTC) *2017 Regional Transportation Guidelines for Metropolitan Planning Organizations* suggests validation for a travel model should include both static and dynamic tests. The static validation tests compare the model's base year traffic volume estimates to traffic counts using the statistical measures and the threshold criteria. Testing the predictive capabilities of the model is called dynamic validation and it is tested by changing the input data for future year forecasts. During the model development process, the three counties performed five dynamic tests including adding lanes to a link in the network, adding/deleting a link, changing link speed, adding a toll fee, and reducing roadway capacity. In addition, MCAG conducted model sensitivity tests as part of their model dynamic testing during CARB's evaluation process of its 2014 SCS, which is summarized and discussed in the Model Sensitivity Analysis section of this report.

MCAG's model validation was based on a traffic count database, the Caltrans Performance Measurement System (PeMS), and HPMS. Based on the results presented in Table 12, the Three-County Model estimates for the MCAG region did not meet the suggested criteria included in the *2017 Regional Transportation Plan Guidelines for Metropolitan Planning Organizations*. One main reason for the model estimates not meeting the criteria is probably due to the lack of traffic data in the MCAG region. However, MCAG is in the process of updating the Three-County Model as part of the second phase of the MIP effort among all the Valley MPOs. CARB staff recommends MCAG update the model with latest demographic and transportation network data, and check if the model validation statistics will improve; if not, MCAG should consider conducting performance validation checks by module to find out specific model improvement needs.

Table 12: Static Validation According to the 2010 CTC's Guidelines

Validation Item	Criteria for Acceptance	Three-County Model for MCAG
Correlation coefficient	at least 0.88	0.85
Percent RMSE	below 40%	56%
Percent of links with volume-to-count ratios within Caltrans deviation allowance	at least 75%	57%

Source: Fehr & Peers (2014). Three-County Model Description.

Model Improvements Since 2012

For the next RTP update anticipated in 2018, MCAG anticipates continuing to refine its travel demand model to better estimate trips and VMT in the region. The immediate and ongoing model improvement efforts include using the latest regional or local demographic data and using the 2010 Census, 2012 American Community Survey (ACS), and the 2012 CHTS travel data for model recalibration and revalidation. Immediate model improvements will also seek to increase model sensitivity to land use and transportation policies. These model improvements will increase the accuracy of estimates and forecasts of external trips, trip modes, and distribution for internal and inter-regional travel; and vehicle speeds (which is critical for air quality analysis).

The additional improvements to the Three-County Model will be built on the outcomes from the Valley-wide model improvements, known as the Valley Model Improvement Program 2 (VMIP2). For example, in VMIP2, the Valley MPOs plan to review and refine the model's TAZ structure based on the 2010 Census geography to update TAZ boundaries and GIS layers.

In addition to the proposed enhancements to the Valley MPO models, CARB staff offers recommendations and suggestions for MCAG to improve the Three-County's forecasting ability in this staff report's Section VI.B (Recommendations). These recommendations should be incorporated into the model improvement program that MCAG is currently developing.

C. EMFAC Model

MCAG used EMFAC 2011 to estimate the GHG emissions associated with its 2014 SCS and the Amended SCS. CARB staff reviewed MCAG's GHG emissions estimation procedures and results and found them to be reasonable.

D. Off-Model Strategies

MCAG incorporated into its Amended SCS GHG emissions reductions from strategies that could not be reflected in the travel demand model. These strategies include enhanced transit, active transportation, intelligent transportation strategies (ITS) and ramp metering, rideshare, passenger rail expansion, and enhanced electric vehicle (EV) penetration. MCAG quantified the GHG benefits from the first three strategies based on a midpoint deployment, between the expanded current practice and aggressive scenarios, cited in the Moving Cooler report by Cambridge Systematics (2009). The following sections highlight of assumptions and funding commitments for these strategies, and CARB staff's recommendation to track implementation progress and effectiveness of these strategies.

CARB staff reviewed the reported input data assumptions, and the analytic methodologies of these strategies, and found them to be reasonable. Since MCAG estimated GHG benefits of three out of six off-model strategies based on a research-based reference (e.g., Moving Cooler), CARB staff recommend MCAG document the implementation plans for each of these strategies and collect transit, active transportation and ITS related data to track progress and effectiveness of the strategies.

Enhanced Transit

The Amended SCS assumes 61 percent higher level of rail and bus transit funding than in the 2014 SCS by assuming additional revenues (i.e., intercity rail and the low carbon transit programs). The additional funding is assumed to provide more frequent bus transit service, fare reduction, and bus rapid transit (BRT). CARB staff recommend MCAG track progress over time on improvement of bus transit service in terms of bus schedule, headway, ridership, route distance/transit seat-mile, or transit fare as measure(s) of this effectiveness of the enhanced transit strategy.

Active Transportation

The Amended SCS assumes that MCAG meets a funding goal to allocate 40 percent of CMAQ funds to active transportation. To monitor the effectiveness of this strategy, MCAG can conduct a survey to estimate the number of vehicular trips and corresponding trip distances that are replaced by bike/walk trips, as a result of this project funding.

ITS and Ramp Metering

The Amended SCS includes quantification of GHG emissions reduction from ITS related strategies that were already included in the 2014 SCS but not previously accounted for. Examples of ITS projects in the region include: variable message signs, active traffic management, incident management, road weather management, signal control coordination, and traveler information. MCAG should monitor the effectiveness of these strategies over time to improve quantification of GHG emission reduction.

Other Off-Model Strategies

Unlike the abovementioned strategies, MCAG quantified the potential GHG benefits from rideshare, passenger rail expansion, and enhanced electric vehicle strategies based on existing program data. The following sections highlight of the assumptions associated with these strategies:

Rideshare

The rideshare program in the MCAG region considers carpooling, vanpooling and other ridesharing programs. The quantification of the associated GHG benefits is based on data from the San Joaquin Valley Air Pollution Control District (SJVAPCD) staff report on Rule 9410 (also known as eTRIP), which is an employer-based commute strategy. Rule 9410 requires worksites in the Valley that have 100 or more employees to promote and implement alternative travel options to their employees. Key assumptions in the estimation include:

- Participation rate by tier level (e.g., 15% for tier 1[43] and 21% for tier 2 worksite[44])
- Number of qualified worksites and number of employees per worksites
- Average home-based work trip length

CARB staff recommend MCAG staff continue to track the annual participation rates, occupancy of rides, and carpooling/vanpooling trip distances to update estimates of GHG benefits for the next SCS.

Passenger Rail Expansion

The extension of Altamont Corridor Express (ACE) passenger rail to Merced, connecting with a planned High Speed Rail station in the downtown area is expected to bring at least 6 daily round trips to the region by 2027. The source of funding for the extension will come from Cap-and-Trade and/or the $400 million funding specifically identified in SB 132.[45] MCAG estimated the associated GHG benefits from the passenger rail expansion based on ridership data from the *ACEforward Draft*

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[43] Tier one worksite is a worksite with 100 to 249 eligible employee, for at least 16 consecutive weeks during the previous fiscal year.
[44] Tier two worksite is a worksite with 250 or more eligible employees, for at least 16 consecutive weeks during the previous fiscal year.
[45] California Legislative Information (2017). Senate Bill No. 132 – Budget Act of 2016. https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB132

Environmental Impact Report prepared by AECOM. Key assumptions in the estimation include:

- Distance from planned station to Merced County line
- Annual ridership

To improve the quantification of GHG benefits from this strategy, MCAG can track the average round trip distance and the number of daily round trips by rail that replace vehicle trips in the region.

Enhanced Electric Vehicle Penetration

MCAG promotes the purchase and use of electric vehicles through its partnership with the SJVAPCD on the "Drive Clean!" and "Charge up!" programs. The local DMV registration fee funded program, "Drive Clean!," offers up to a $3,000 rebate to Valley residents and businesses for purchase or lease of new, clean-air vehicles. Also, the "Charge up!" provides funding for public agencies and businesses in the Valley to install EV chargers for public access, which will supporting existing EV owners and encourage the growth of clean technology in the Valley. Key assumptions in the estimation include:

- "Drive Clean" program GHG benefits claimed beginning in 2020
- Number and type of EVs purchased in Merced County
- Vehicles were classified as pure electric (BEV) or hybrid electric (PHEV)
- Light-duty vehicle survival rates from EMFAC 2011

III. Model Sensitivity Analysis

Model sensitivity tests are used to study the responsiveness of the travel demand model to changes in selected input variables. The responsiveness, or sensitivity, of the model to changes in key inputs indicates whether the model can reasonably estimate the anticipated change in VMT and associated GHG emissions resulting from the policies in the SCS. A sensitivity test usually assumes one input variable change at a time and examines the range of output change. Sensitivity analyses are not intended to quantify model inputs or outputs or provide analyses of actual modeled data.

CARB requested that MCAG conduct a series of sensitivity analyses for its model using the following variables.[46]

- Auto operating cost
- Household income distribution
- Transit frequency
- Residential density
- Proximity to transit

Following the methodology in CARB's *Description of Methodology for ARB Staff Review of Greenhouse Gas Reductions from Sustainable Communities Strategies (SCS) Pursuant to SB 375* (2011), CARB staff reviewed results from model sensitivity test runs on land use and transportation-related variables. Model sensitivity test results were compared to findings in the empirical literature as discussed in the CARB-funded policy briefs and corresponding technical background documents[47] in order to evaluate the model's ability, given the data inputs and assumptions, to produce reasonable estimates. In those cases where the findings were corroborated by the empirical literature, the findings were referred to as either sensitive directionally, meaning that the direction of change was consistent with findings in the empirical literature, or sensitive in magnitude, meaning that the amount of change predicted was consistent with the literature. In those cases where sensitivity analysis findings could not be specifically corroborated by the empirical literature, CARB staff indicated whether the model was sensitive directionally, meaning that changes in model inputs resulted in expected changes to model outputs.

A. Auto Operating Cost Sensitivity Test

Auto operating cost is an important factor influencing travelers' auto use. MCAG's definition of auto operating cost for the region includes fuel price only. To determine the

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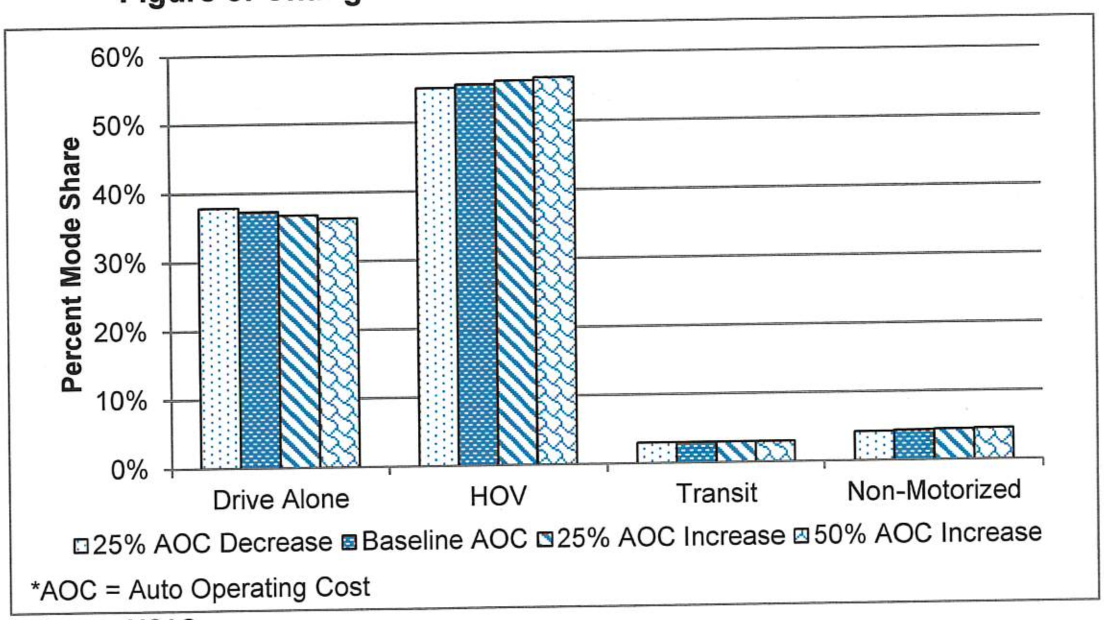
[46] CARB staff assisted MCAG in conducting the sensitivity tests by preparing input files for the income distribution test and providing general procedures on how to perform different test runs.

[47] The policy briefs and technical background documents that identify the impacts of key transportation and land use policies on vehicle use and GHG emissions, based on the scientific literature, can be found at http://arb.ca.gov/cc/sb375/policies/policies.htm

responsiveness to the Three-County Model to auto operating cost, three alternative scenarios were tested: 1) 25 percent decrease; 2) 25 percent increase; and 3) 50 percent increase from the baseline. When the auto operating cost increases, travelers are expected to drive less. Conversely, when auto operating cost decreases, travelers are expected to drive more. In relation to mode share, it is expected that as auto operating cost increases, the number of drive-alone trips would shift to shared-ride, transit, bicycling, and/or walking.

summarizes the response of mode share to the change in auto operating cost. As expected, as auto operating cost increases, the percentage of drive alone trips decreases while percentages of other modes such as shared-ride or high occupancy vehicle (HOV), and non-motorized trips increase, although the percentage increases in these modes are small. Due to limitations of existing transit service within the region and high commute rates outside of the region, it is reasonable to observe subtle changes in mode share corresponding to the change in auto operating cost. Even when auto operating cost increases or decreases, residents in the MCAG region still primarily rely on the auto mode to reach their destinations.

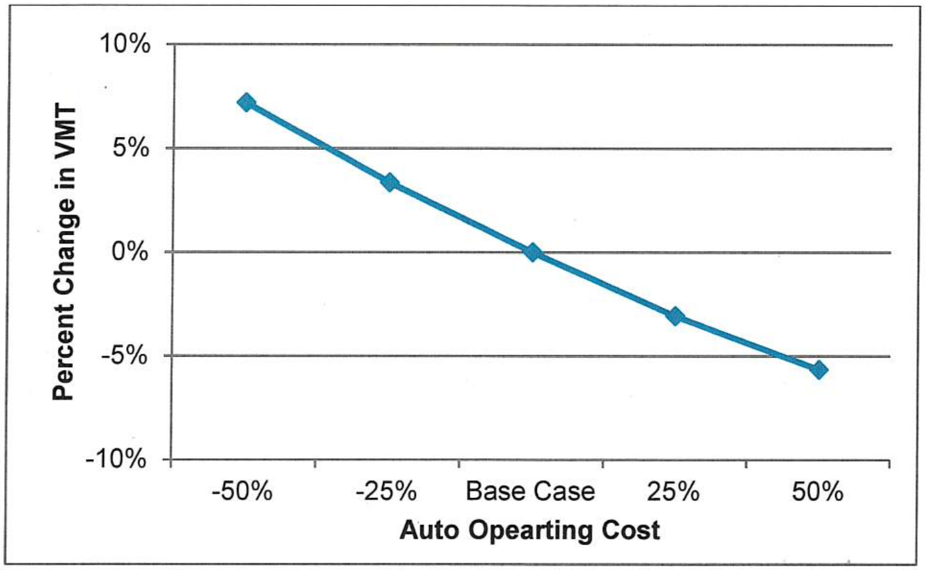
Figure 8: Change of Mode Share and Auto Operating Cost



Source: MCAG.

Figure 9 shows modeled VMT changes with respect to changes in auto operating cost. As auto operating cost increases, the model shows a decrease in VMT. The percentage of VMT change from the base case in each test scenario ranged from -5.7 percent to 7.2 percent.

Figure 9: VMT Change and Auto Operating Cost



Source: MCAG.

Table 13 summarizes the VMT changes related to changes in auto operating cost. As auto operating cost increases, the model shows a decrease in VMT, which is expected. CARB staff compared the modeled VMT to the expected range of VMT estimated based on elasticity[48] of VMT with respect to the change in auto operating cost from the empirical literature. Studies showed that the short-run elasticities (less than five years) of VMT with respect to auto operating cost ranged from -0.026 (Hymel, Small and Van Dender, 2010), -0.195 (Burt and Hoover, 2006), and -0.091 to -0.093 (Boilard, 2010). The long-run elasticities (greater than five years) ranged from -0.131 (Small and Van Dender, 2010), and -0.29 to -0.31 (Goodwin et al., 2004).[49] The modeled VMT for each of the tests changed in the expected direction and fell within the expected range.

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[48] Elasticity is defined as the percent change in one variable divided by the percent change in another variable.

[49] The studies cited this section regarding elasticity of VMT with respect to the change in auto operating cost are mentioned in the ARB-funded policy brief prepared by Giovanni Circella and Susan Handy, "Impacts of Gas Price on Passenger Vehicle Use and Greenhouse Gas Emissions" regarding the case studies mentioned in this section, which can be found at http://www.arb.ca.gov/cc/sb375/policies/gasprice/gasprice_brief.pdf

Table 13: Auto Operating Costs – Sensitivity Results

Test	Modeled VMT	Expected VMT (Short-Run)	Expected VMT (Long-Run)
50% Decrease from Base Case	7,558,562	7,120,394 - 7,860,633	7,437,639 - 8,248,377
25% Decrease from Base Case	7,286,667	7,085,144 - 7,455,264	7,243,7 67 - 7,649,136
Base Case (2008)	7,049,895	--	--
25% Increase from Base Case	6,833,895	6,644,526 - 7,014,646	6,450,654 - 6,856,023
50% Increase from Base Case	6,651,224	6,239,157 - 6,979,396	5,851,413 - 6,662,151

Source: -0.026 (Small and Van Dender, 2010), -0.195 (Burt and Hoover, 2006), and -0.091 to -0.093 (Boilard, 2010) for short-run; -0.131 (Small and Van Dender, 2010), and -0.29 to -0.31 (Goodwin et al., 2004) for long-run.

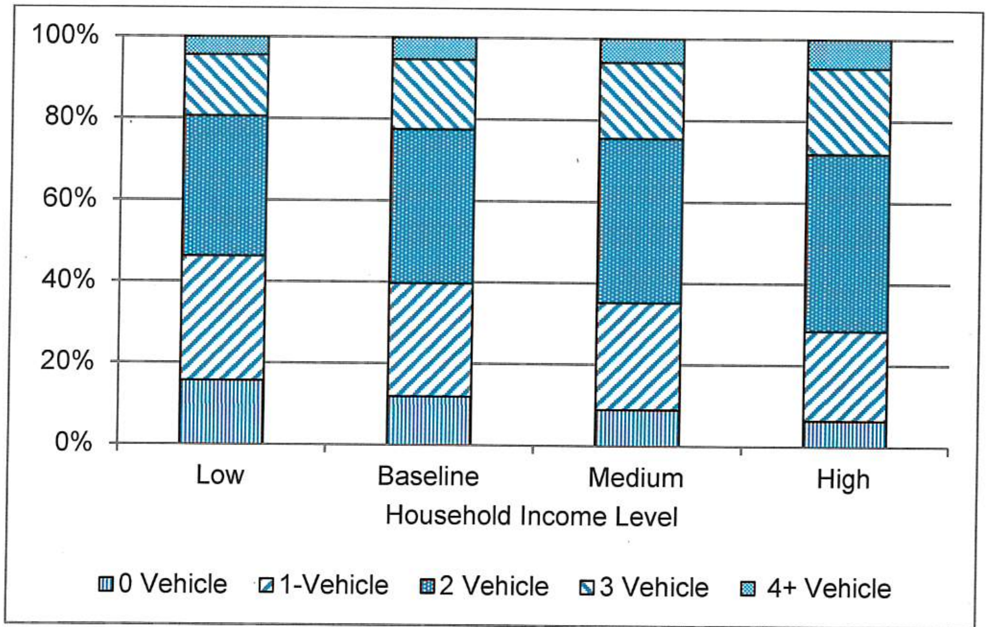
B. Household Income Distribution

Household income distribution plays an important role in the trip generation step of the travel demand model. Household income is linked to the available number of vehicles which then impacts the total number of trips. The expectation of the income distribution sensitivity testing is that as household income increases, so will the proportion of households with a greater number of vehicles. Given the predetermined trip generation rates in the model, if a household has more vehicles, it generates more trips and more VMT. If the income distribution shifts downward, it is expected that the vehicle ownership model will predict more households with fewer available vehicles and similarly, fewer trips and less VMT.

To test the responsiveness of the model to changes in household income distribution, 3 testing scenarios were designed and tested using the average household income as an indicator, while controlling the total number of households at approximately the same as in the base case. The 2008 average household income of $50,243 from the model was used as the base case. CARB staff designed three testing scenarios with average household incomes of Low ($42,101), Medium ($55,817) and High ($66,117).

Figure 10 summarizes the auto ownership changes under the different household income scenarios. As expected, households shift towards having more vehicles available as household income increases, and vice versa.

Figure 10: Household Vehicle Ownership Type Distribution



Source: MCAG.

There is relatively little in the empirical literature that cites the direct effect of household income on household VMT. Murakami and Young (1997)[50] report that low income households make 20 percent fewer trips than other households. Since this number counts all trips (including walking and transit), the effect on VMT is even more significant: VMT per household in low income households is about half of that in other households. Figure 11 shows the modeled VMT for each test scenario of household income distribution. The test results showed the model responds to changes in household income distribution in the expected direction (i.e., more income correlates with more VMT), but the degree of change cannot be evaluated since no elasticities specific to income were identified in the empirical literature. However, the responsiveness of the model to the change in average household income is similar to that of other MPO models in California.

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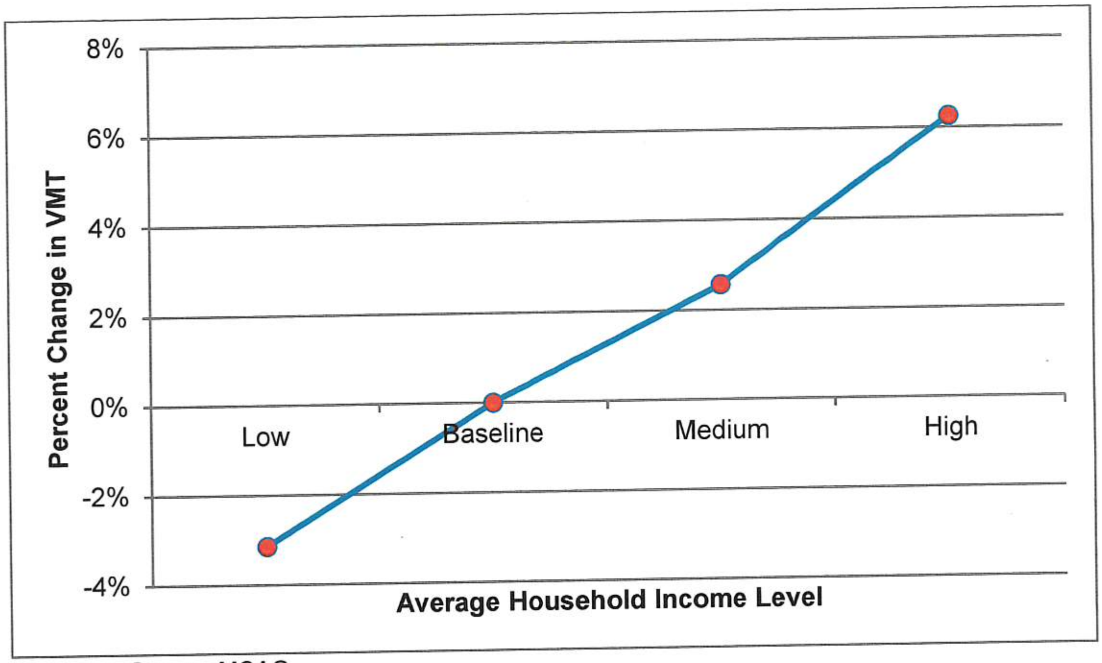
[50] Murakami, and Young (1997) Daily Travel by Persons with Low Income. Accessed in 2018 from https://nhts.ornl.gov/1995/Doc/LowInc.pdf.

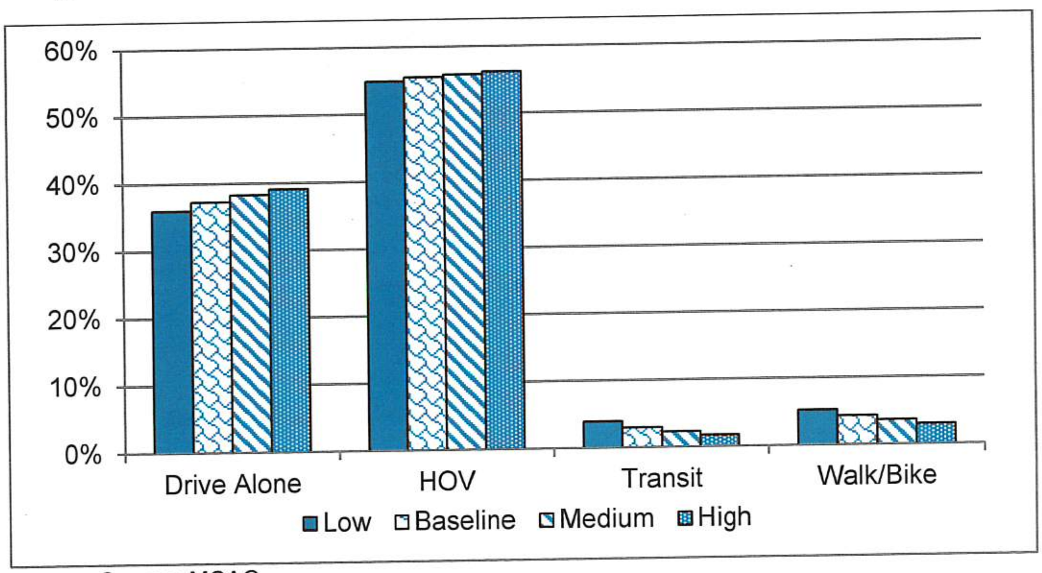
Figure 11: VMT Changes for Household Income Distribution Scenarios



Source: MCAG.

The impact of household income on daily mode share was also examined. It is expected that as household income increases, travelers will be more likely to drive autos or use the auto mode in general. As shown in Figure 12, the mode share responded to household income distribution changes as expected. The drive alone share increased when household income increased while transit and non-motorized trips decreased.

Figure 12: Mode Share Response to Household Income Changes



Source: MCAG.

C. Transit Frequency

Transit service frequency is a key determinant of transit ridership. To determine the responsiveness of the Three-County Model to transit frequency, four alternative frequencies were tested: 1) 50 percent increase; 2) 50 percent decrease; 3) 75 percent decrease; and 4) 100 percent decrease from the base case. As transit service becomes more frequent, transit ridership is expected to increase, and conversely, transit ridership is expected to decline with decreasing frequency.

Table 14 summarizes the response of ridership to the change in transit frequency. The test results were compared to expected values based on the empirical literature which suggests that a 1 percent increase in frequency results in a 0.5 percent increase in ridership.[51] As expected, the modeled transit ridership decreases as transit frequency declines compared to base case, and vice versa. The change in magnitude is not as much as the nationwide average, probably due to less public transit service coverage and transit users in the MCAG region relative to urban transit centers that were studied in the national surveys. Based on knowledge of transit ridership in the neighboring counties, for low income in the rural area, workers have to rely on transit service to get to work or other activities regardless how frequent the bus transit runs in the area.

Table 14: Transit Frequency Impact on Ridership

Test	Modeled Transit Ridership	Expected Transit Ridership
100% Decrease from Base Case	25,841	13,898
75% Decrease from Base Case	26,028	17,373
50% Decrease from Base Case	26,573	20,847
Base Case (2008)	27,796	--
50% Increase from Base Case	29,396	34,745

Source: Evans (2004), bus ridership increases by 0.5% for each 1% increase in service frequency. Taylor et al. (2009), total ridership increases by 0.5% for each 1% increase in service frequency.

Figure 13 shows the change in mode share as transit frequency changes. When transit frequency increases, it is expected that transit mode share will increase, as travelers are more attracted to use public transit when wait time is shortened. The test results do not show a significant difference from one test scenario to another. It is the understanding that transit mode share in the MCAG region is overall very low due to limited transit coverage in the model base year (2008). Although the magnitude of change in mode share is subtle, the model is reasonably sensitive to change in transit frequency directionality. For example, with a 50 percent increase in transit frequency,

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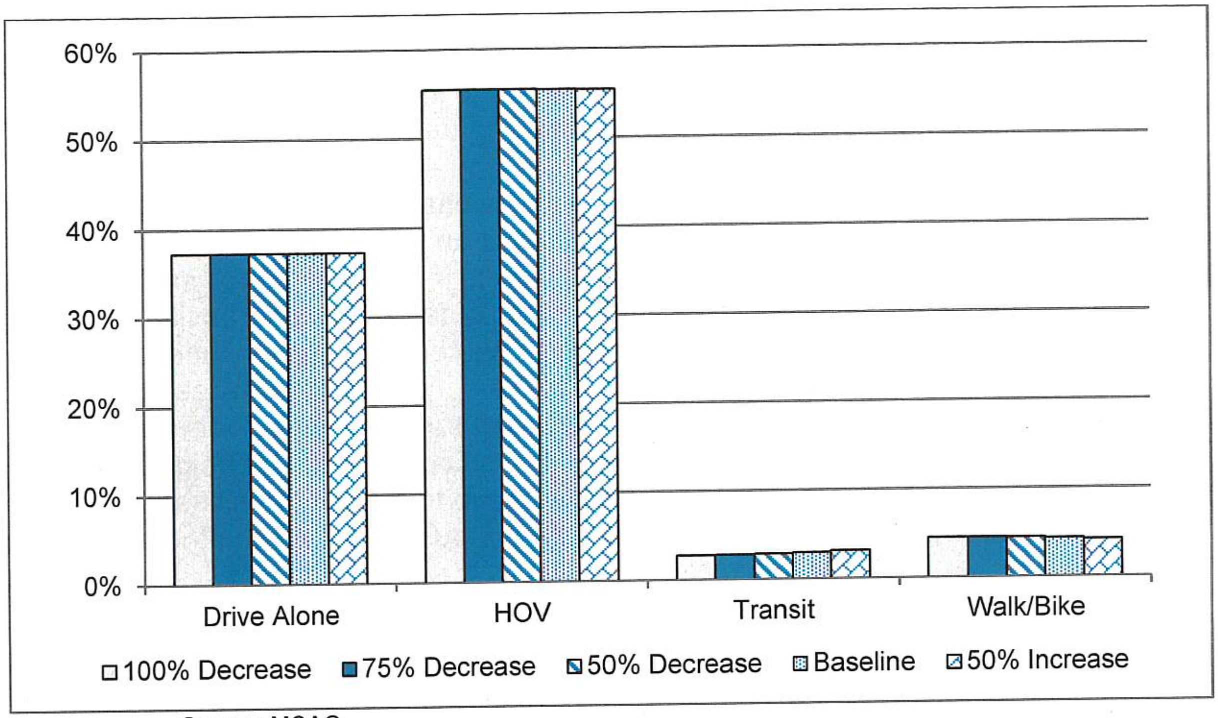
[51] The empirical literature cited in this section regarding elasticity of VMT with respect to the change in transit frequency are mentioned in the ARB-funded policy brief by Handy and Lovejoy, "Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions" regarding the case studies mentioned in this section, which can be found at http://www.arb.ca.gov/cc/sb375/policies/transitservice/transit_brief.pdf

the transit mode share peaks with 3.1 percent of the total trips, whereas the 100 percent decrease in transit frequency results in a transit mode share of 2.8 percent of total trips.

Figure 13: Impact of Transit Frequency on Mode Share



Source: MCAG.

D. Residential Density

Residential density is usually defined as the number of housing units per acre. Increasing residential density has been considered an effective land use strategy to reduce VMT in a region because denser residential developments tend to be associated with fewer trips and less VMT. MCAG conducted three tests to examine the model's responsiveness to change in residential density: 1) 25 percent increase; 2) 50 percent increase; and 3) 25 percent decrease from the base case.

Most of the studies cited in the empirical literature that relate to residential density focus on overall population density, which is probably the best proxy for residential density. As expected, when residential density increases, VMT decreases, and vice versa (Table 15). MCAG's sensitivity analysis indicates that the model is directionally sensitive to changes in residential density. However, not all changes of VMT in magnitude are within the expected range, which is probably because MCAG has mostly rural areas and very limited urban areas, similar to some other Valley counties; the residential density at the TAZ level stayed almost unchanged from one test scenario to another.

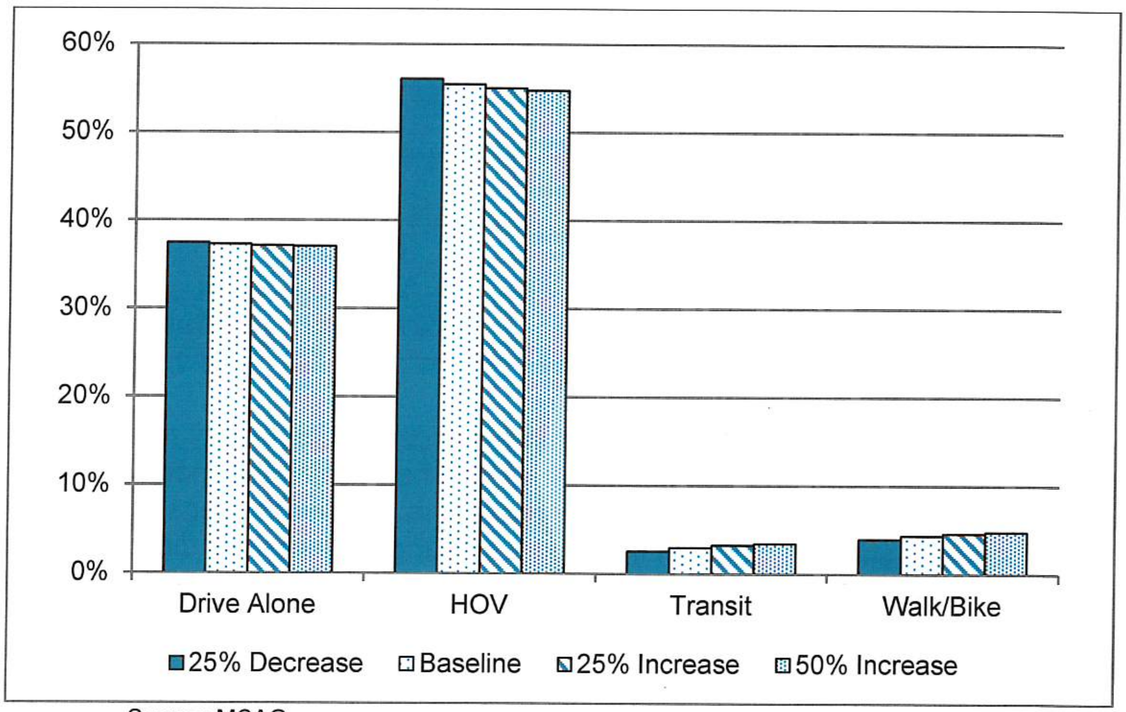
Table 15: Impact of Residential Density on VMT

Test	Modeled VMT	Expected VMT
25% Decrease from Base Case	7,168,430	7,138,019 - 7,261,392
Base Case (2008)	**7,049,895**	--
25% Increase from Base Case	6,996,267	6,838,398 - 6,961,771
50% Increase from Base Case	6,968,942	6,626,901 - 6,873,648

Source: Boarnet and Handy (2013) the impacts of population density on VMT range from -0.05 to -0.12.

As residential density in the region increases, test result also shows that mode shares for auto stayed almost unchanged across scenarios (Figure 14). This is possibly due to the nature of the MCAG model lacking sensitivity to land use, especially the mode choice component.

Figure 14: Impact of Residential Density on Mode Share



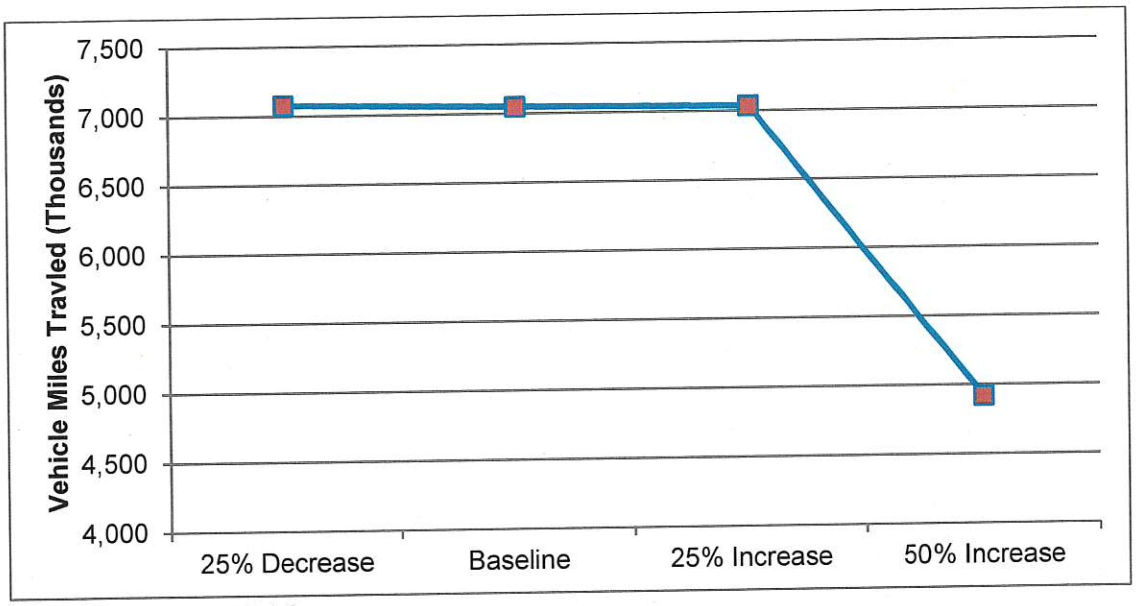
Source: MCAG.

E. Proximity to Transit

The responsiveness of the Three-County Model to residential proximity to transit was tested by reallocating households to be along existing transit corridors (i.e., in transit-oriented development areas). It is expected that households relocated to transit corridors would be more likely to use transit which would, in turn, increase transit ridership and decrease household travel cost. MCAG conducted three tests to examine the model's responsiveness to change in proximity to transit: 1) 25 percent increase; 2) 50 percent increase; and 3) 25 percent decrease from the base case. When more households are located near transit, more households would be expected to use transit service instead of auto, which leads to a decrease in VMT, and vice versa.

Figure 14 shows the VMT response to changes in proximity to transit. The model's change is sensitive directionally to the change in residential density near transit, though small in magnitude when changes in residential density near transit are less than 25 percent from baseline.

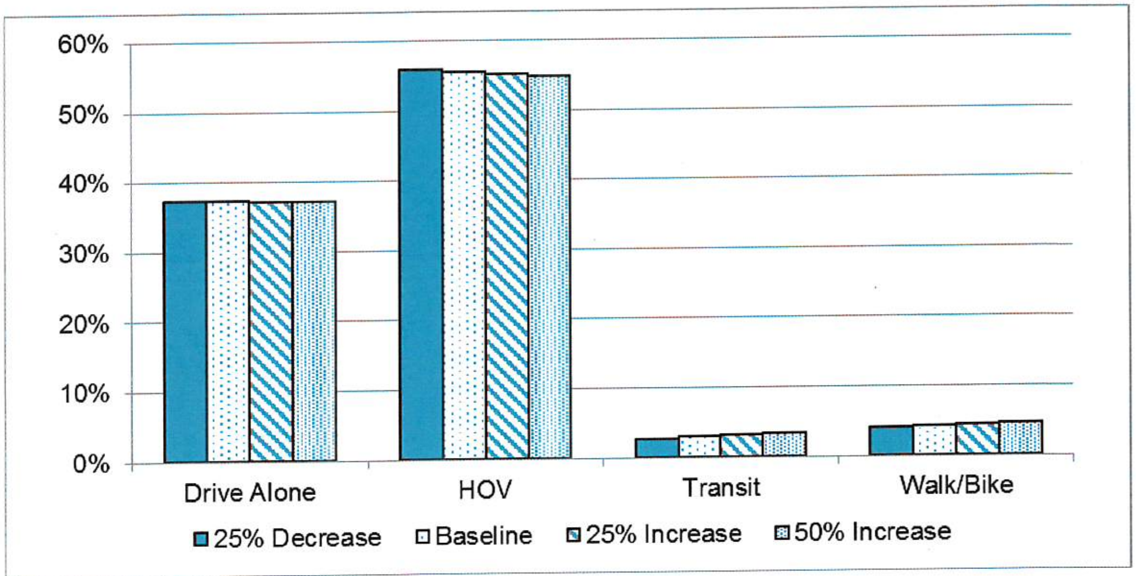
Figure 15. Impact of Residential Density near Transit on VMT



Source: MCAG.

Figure 16 summarizes the change in mode share as residential density near transit changes. Though not large in magnitude, transit and non-motorized mode shares increase slightly, while overall auto mode decreases, as residential density increases near transit stops or stations. Overall the model's change is sensitive directionally to the change in residential density near transit based on the change in VMT. Similar to other regions in the Valley, the low magnitude of change from scenario to scenario is probably due to the limited transit options in the region.

Figure 16. Mode Share Changes in Response to Change in Residential Density near Transit



Source: MCAG.

APPENDIX B: MCAG Modeling Data Table

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035		Data Source(s)
			With Project*	Without Project	With Project	Without Project	
DEMOGRAPHICS							
Total population	239,836	253,183	302,972	302,972	383,397	383,397	2012 Planning Center Demographic Forecasts
Group quarters population	4,428	4,820	8,750	8,750	15,330	15,330	2012 Planning Center Demographic Forecasts
Total employment (employees)	68,800	68,800	74,293	74,293	86,732	86,732	2012 Planning Center Demographic Forecasts
Average unemployment rate (%)	10%	12.60%	NA	NA	NA	NA	Bureau of Labor Statistics- Labor Force by County
Total number of households	72,065	79,124	90,047	90,047	112,389	112,389	2012 Planning Center Demographic Forecasts
Persons per household	3.27	3.14	3.45	3.45	3.51	3.51	2012 Planning Center Demographic Forecasts
Auto ownership per household	NA	NA	NA	NA	NA	NA	
Median household income	NA	42,449	NA	NA	NA	NA	2012 Planning Center Demographic Forecasts
LAND USE [4]							
Total acres within MPO	1,265,613	1,265,613	1,265,613	1,265,613	1,265,613	1,265,613	Table A-18 Dept of Conservation Farmland Monitoring Program
Total resource area acres (CA GC Section 65080.01)	NA	NA	NA	NA	NA	NA	
Total farmland acres (CA GC Section 65080.01)	NA	593,463	NA	NA	NA	NA	Total farmland (including local, statewide, unique and prime) FMMP 2008, 2010- Envision Tomorrow /GIS analysis (Trend, Scenario C)
Total developed acres (including existing)	NA	NA	NA	NA	NA	NA	Envision Tomorrow - Trend, Scenario C (Acres Consumed)

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035		Data Source(s)
			With Project*	Without Project	With Project	Without Project	
Total commercial developed acres (new growth only)	NA	NA	NA	NA	NA	NA	Envision Tomorrow - Trend, Scenario C (Acres Consumed)
Total residential developed acres (new growth only)	NA	NA	NA	NA	NA	NA	Envision Tomorrow - Trend, Scenario C (Acres Consumed)
Total housing units	77,138	84,813	90,262	90,306	112,178	112,198	TAZ files for 2020 and 2035; 2012 Planning Center
Housing vacancy rate (Percentage)	6.58%	6.71%	NA	NA	NA	NA	2012 Planning Center Demographic Forecasts
Total single-family detached housing units	58,318	65,417	66,407	67,323	77,386	86,303	TAZ files for 2020 and 2035; 2012 Planning Center
Total small-lot single family detached housing units	NA	NA	NA	NA	NA	NA	NA
Total conventional-lot single family detached units	NA	NA	NA	NA	NA	NA	NA
Total large-lot single family detached units	NA	NA	NA	NA	NA	NA	NA
Total single-family attached housing units	NA	NA	2705	2476	2899	2669	TAZ files for 2020 and 2035; 2012 Planning Center
Total multi-family housing units	13,245	13,655	15,770	15,326	26,238	17,687	TAZ files for 2020 and 2035; 2012 Planning Center
Total mobile home units & other	5,575	5,741	5,380	5,181	5,655	5,539	TAZ files for 2020 and 2035; 2012 Planning Center
Total infill housing units	NA	NA	NA	NA	NA	NA	NA
Total mixed use buildings	NA	NA	NA	NA	NA	NA	Envision Tomorrow - Trend, Scenario C (Buildings Tab)

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035		Data Source(s)
			With Project*	Without Project	With Project	Without Project	
Total housing units within 1/4 mile of transit stations and stops	NA	64,219	NA	NA	NA	NA	TAZ 2008, TAZ Scenario C - GIS analysis (households instead of housing units)
Total housing units within 1/2 mile of transit stations and stops	NA	70,093	NA	NA	NA	NA	TAZ 2008, TAZ Scenario C - GIS analysis (households instead of housing units)
Total employment within 1/4 mile of transit stations and stops	NA	52,376	NA	NA	NA	NA	TAZ 2008, TAZ Scenario C - GIS analysis
Total employment within 1/2 mile of transit stations and stops	NA	55,086	NA	NA	NA	NA	TAZ 2008, TAZ Scenario C - GIS analysis
TRANSPORTATION SYSTEM							
Freeway general purpose lanes – mixed flow lane miles							
Freeway	675	NA	692	692	710	710	3-county model
Arterial (lane miles)	1,482	NA	1,521	1,521	1,580	1,580	3-county model
Collector (lane miles)	556	NA	559	559	559	559	3-county model
Local (lane miles)	326	NA	327	327	327	327	3-county model
Local, express bus, and neighborhood shuttle operation miles	NA	NA	NA	NA	NA	NA	NA
Bus rapid transit bus operation miles	NA	NA	NA	NA	NA	NA	NA
Passenger rail operation miles	NA	NA	NA	NA	NA	NA	NA
Transit total daily vehicle service hours	NA	NA	NA	NA	NA	NA	NA

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035		Data Source(s)
			With Project*	Without Project	With Project	Without Project	
Bicycle and pedestrian trail/lane miles	NA	NA	NA	NA	NA	NA	NA
Vanpool (total riders per weekday)	NA	NA	NA	NA	NA	NA	NA
TRIP DATA [5]							
Number of trips by trip purpose							
Home-Work	NA	171,867	199,012	201,517	227,395	239,989	3-county model
Home-Shop	NA	101,265	117,246	120,869	141,107	150,340	3-county model
Home-Other	NA	455,122	527,310	530,610	637,436	688,703	3-county model
Work-Other	NA	22,293	26,816	26,696	30,981	30,969	3-county model
Other-Other	NA	188,507	221,471	220,928	261,648	262,521	3-county model
MODE SHARE							
Vehicle Mode Share (Peak Period)							
SOV (% of trips)	NA	38.02%	37.77%	37.76%	37.27%	36.88%	3-county model
SharedRide 2(% Trips)	NA	22.14%	22.13%	22.18%	22.17%	22.78%	3-county model
SharedRide 3+ (% Trips)	NA	34.42%	34.98%	35.02%	35.52%	35.50%	3-county model
Transit (% of trips)	NA	1.97%	1.82%	1.78%	1.77%	1.75%	3-county model
Walk (% Trips)	NA	0.84%	0.83%	0.82%	0.83%	0.80%	3-county model
Bike (% Trips)	NA	2.61%	2.48%	2.44%	2.43%	2.29%	3-county model
Number of Trips by Vehicle Mode Share (Peak Period)							
SOV	NA	65,351	75,163	76,092	84,757	88,501	3-county model
SharedRide 2	NA	38,050	44,037	44,688	50,421	54,679	3-county model
SharedRide 3+	NA	59,154	69,614	70,574	80,770	85,189	3-county model
Transit	NA	3,386	3,616	3,591	4,027	4,205	3-county model

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035		Data Source(s)
			With Project*	Without Project	With Project	Without Project	
Walk	NA	1,435	1,645	1,649	1,898	1,909	3-county model
Bike	NA	4,491	4,937	4,923	5,521	5,508	3-county model
Vehicle Mode Share (Whole Day)							
SOV (% of trips)	NA	37.27%	37.06%	37.06%	36.59%	36.23%	3-county model
SharedRide 2(% Trips)	NA	21.70%	21.71%	21.76%	21.77%	22.38%	3-county model
SharedRide 3+ (% Trip)	NA	33.74%	34.32%	34.37%	34.87%	34.87%	3-county model
Transit (% of trips)	NA	2.96%	2.76%	2.71%	2.72%	2.64%	3-county model
Walk (% Trips)	NA	1.15%	1.14%	1.13%	1.14%	1.09%	3-county model
Bike (% Trips)	NA	3.17%	3.02%	2.98%	2.92%	2.78%	3-county model
Number of Trips by Vehicle Mode Share (Whole Day)							
SOV	NA	64,061	73,746	74,674	83,196	86,942	3-county model
SharedRide 2	NA	37,299	43,207	43,855	49,493	53,716	3-county model
SharedRide 3+	NA	57,986	68,302	69,258	79,283	83,689	3-county model
Transit	NA	5,091	5,496	5,451	6,180	6,346	3-county model
Walk	NA	1,974	2,259	2,269	2,598	2,626	3-county model
Bike	NA	5,455	6,003	6,009	6,645	6,670	3-county model
Average weekday trip length (miles)							
SOV	NA	16.34	16.25	16.29	18.95	18.5	3-county model
SharedRide 2	NA	18.75	18.15	18.20	18.74	18.87	3-county model
SharedRide 3+	NA	17.31	16.60	16.76	18.06	18.51	3-county model
Transit	NA	16.27	16.40	16.31	17.26	16.51	3-county model
Walk/Bike	NA	2.78	2.89	2.87	3.01	3	3-county model
Average weekday travel time (minutes)							

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035		Data Source(s)
			With Project*	Without Project	With Project	Without Project	
SOV	NA	22.73	22.89	22.92	25.57	25.01	3-county model
SharedRide 2	NA	25.53	25.14	25.19	25.67	25.77	3-county model
SharedRide 3+	NA	23.89	23.39	23.56	24.86	25.29	3-county model
Transit	NA	21.88	22.22	22.12	23.07	22.47	3-county model
Walk/Bike	NA	7.38	7.58	7.54	7.76	7.72	3-county model
TRAVEL MEASURES							
Total VMT per weekday for passenger vehicles (ARB vehicle classes of LDA, LDT1, LDT2 and MDV) (miles)	5,289,631	NA	6,326,090	6,345,547	7,945,751	8,070,539	3-county model+EMFAC2011
SB 375 VMT (-XX) per weekday for passenger vehicles (ARB vehicle classes of LDA, LDT1, LDT2 and MDV) (miles)	3,297,489	NA	3,888,114	3,905,340	4,949,366	5,073,439	3-county model+EMFAC2011
Total II (Internal) VMT per weekday for passenger vehicles (miles)	2,558,829	NA	2,813,853	2,873,260	3,322,382	3,517,032	3-county model+EMFAC2011
Total IX/XI VMTper weekday for passenger vehicles (miles)	738,660	NA	1,074,261	1,032,080	1,626,984	1,556,407	3-county model+EMFAC2011
Total XX VMT per weekday for passenger vehicles (miles)	1,992,142	NA	2,437,976	2,440,207	2,996,385	2,997,100	3-county model+EMFAC2011
Congested Peak Hour VMT on	NA	NA	NA	NA	NA	NA	NA

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035		Data Source(s)
			With Project*	Without Project	With Project	Without Project	
freeways (Lane Miles, V/C ratios >0.75)							
Congested Peak VMT on all other roadways (Lane Miles, V/C ratios >0.75)	NA	NA	NA	NA	NA	NA	NA
CO2 EMISSIONS[6]							
Total CO2 emissions per weekday for passenger vehicles (ARB vehicle classes LDA, LDT1, LDT2, and MDV) (tons)	2,555	NA	2,990	2,998	3,847	3,895	EMFAC2011
SB 375 CO2 emissions (-XX) per weekday for passenger vehicles (ARB vehicle classes LDA, LDT1, LDT2, and MDV) (tons)	1,593	NA	1,838	1,845	2,396	2,449	EMFAC2011
Total II (Internal) CO2 emissions per weekday for passenger vehicles (tons)	1,236	NA	1,330	1,357	1,608	1,698	EMFAC2011
Total IX / XI trip CO2 emissions per weekday for passenger vehicles (tons)	357	NA	508	488	788	751	EMFAC2011
Total XX trip CO2 emissions per weekday for	962	NA	1,152	1,153	1,451	1,446	EMFAC2011

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035		Data Source(s)
			With Project*	Without Project	With Project	Without Project	
passenger vehicles (tons)							
Local, express bus, and neighborhood shuttle operation miles	NA	NA	NA	NA	NA	NA	NA
Bus rapid transit bus operation miles	NA	NA	NA	NA	NA	NA	NA
Passenger rail operation miles	NA	NA	NA	NA	NA	NA	NA
Transit total daily vehicle service hours	NA	NA	NA	NA	NA	NA	NA
Bicycle and pedestrian trail/lane miles	NA	NA	NA	NA	NA	NA	NA
Vanpool (total riders per weekday)	NA	NA	NA	NA	NA	NA	NA
INVESTMENT (Billions)							
Total RTP Expenditure (Year XXXX $)	NA	NA	NA	NA	NA	NA	MCAG 2014 RTP Amend. 1
Highway capacity expansion (S)	NA	NA	NA	NA	NA	NA	MCAG 2014 RTP Amend. 1
Other road capacity expansion ($)							MCAG 2014 RTP Amend. 1
Roadway maintenance ($)	NA	NA	NA	NA	NA	NA	MCAG 2014 RTP Amend. 1
BRT projects ($)	NA	NA	NA	NA	NA	NA	MCAG 2014 RTP Amend. 1
Transit capacity expansion ($)	NA	NA	NA	NA	NA	NA	MCAG 2014 RTP Amend. 1
Transit operations ($)							MCAG 2014 RTP Amend. 1
Bike and pedestrian projects ($)	NA	NA	NA	NA	NA	NA	MCAG 2014 RTP Amend. 1

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035		Data Source(s)
			With Project*	Without Project	With Project	Without Project	
TRANSPORTATION USER COSTS							
Vehicle operating costs (Year XXXX $ per mile)	0.11	0.18	0.18	0.18	0.19	0.19	NA
Gasoline price (Year XXXX $ per gallon)	2.24	3.65	4.46	4.46	6.06	6.06	NA
Average transit fare (Year XXXX $)	NA	NA	NA	NA	NA	NA	NA
Parking cost (Year XXXX $)	None	None	None	None	None	None	NA

Source: MCAG Data Table, April 2018

NA = Not Available

*The "Without Project" equates to Scenario A of the RTP before model improvements and the "With Project" equates to the Preferred Scenario after model improvements; i.e., the Amended SCS.

APPENDIX C: MCAG SCS Off-Model Strategy Quantification Methodology

Merced "Offmodel" GHG Reduction Summary

BASELINE (RTP/SCS Scenario C) **5.9%**

Measure/Strategy	2035 GHG Reduction	Reference
Urban transit Transit fare reduction Express transit	0.60%	*See Transit, Active Transport, ITS tab*
Passenger rail commutes (Amtrak & ACE)	0.34%	*See ACE Rail tab*
ITS/Ramp Meters	0.36%	*See Transit, Active Transport, ITS tab*
Rideshare / Vanpools	1.60%	*See Rule 9410 tab*
Bicycle (and retrofits) Pedestrian (and retrofits)	0.36%	*See Transit, Active Transport, ITS tab*
Additional alt. fuel / EV subsidies	0.36%	*See EV tab*
EV charger installation	Not analyzed	-
Fee on gas cars ("feebates")	Not analyzed	-
sum of all transportation measures	3.6%	

parking restrictions & pricing	Not analyzed	-
Smaller lots (RTP scen. C)	Included	*3 county model, Scenario C*
Denser, plus infill (about 1/3)	Not analyzed	-
sum of all land use measures	NA	

Total GHG Reduction **10%**

EV Incentives GHG Reduction Analysis
Merced County

Funding Year	BEV, vehicles	PHEV, vehicles	
2014	8	6	*Note: not a full funding year*
2015	26	10	
2016	32	11	
2017	29	37	
Total	95	64	
Average Vehicles/Yea	29	19	
Cumulative by 2035	464	309	

**Source: SJVAPCD Data for Merced County*

Note: Average number of EVs funded uses three-year average (2015-2017) since 2014 was not a full funding year. Analysis is conservative as it does not account for annual growth in EVs funded as observed in the APCD data. Assumes local funding will continue through 2035.Assumes state incentive expires by 2020.

BEV Emission Reduction, 2035					
MCAG LDA Pop (EF11)	EV Pop	EF11 CO2, tons/day	CO2 tons/vehicle/da	CO2 Reduced, tons/day	% Reduced
150,843	391	2,613	0.0173	7	-
Merced SCS CO2, tons/day		2396			0.3%

PHEV Emission Reduction, 2035					
MCAG LDA Pop (EF11)	EV Pop	EF11 CO2, tons/day	CO2 tons/vehicle/day	CO2 Reduced, tons/day	% Reduced
150,843	260	2,613	0.0069	2	-
Merced SCS CO2, tons/day		2396			0.1%

Total Reduction 0.4%

Note: PHEV CO2 emissions rate is based on CARB assumption of 0.4 utility factor (Source: EF14 Tech Document). This means that only 40 percent of the VMT assumed to be all-electric.

EV Survival Rates (EF11, 2035)

MY	AGE	EV	BEV Population	PHEV Population	Adj BEV	Adj PHEV
2035	0	1.00000	29	19	29	19
2034	1	1.00000	29	19	29	19
2033	2	0.97207	29	19	28	19
2032	3	0.95722	29	19	28	19
2031	4	0.94659	29	19	27	18
2030	5	0.93125	29	19	27	18
2029	6	0.91456	29	19	27	18
2028	7	0.89367	29	19	26	17
2027	8	0.86859	29	19	25	17
2026	9	0.83739	29	19	24	16
2025	10	0.80255	29	19	23	16
2024	11	0.76270	29	19	22	15
2023	12	0.72038	29	19	21	14
2022	13	0.67436	29	19	20	13
2021	14	0.61938	29	19	18	12
2020	15	0.56553	29	19	16	11
2019	16	0.50578	0	0	0	0
2018	17	0.44258	0	0	0	0
2017	18	0.38218	0	0	0	0
2016	19	0.33257	0	0	0	0
2015	20	0.29056	0	0	0	0
2014	21	0.25525	0	0	0	0
		Totals	464	309	391	260

ACE Rail GHG Reduction Analysis
Merced County

Adjustment Factor for Transit Dependency: 0.83

Assumptions:

Station	2025 Annual Ridership (thousands)	2040 Annual Ridership (thousands)	Source
Merced	215	250	*ACEforward Draft Environment Impact Report, Appendix E*
Livingston	175	240	

Station	2025 Average Length (miles)	2040 Average Length (miles)	Source
Merced	25	25	Miles from Planned Station to Merced County line, Google Maps
Livingston	10	10	

VMT Reduction Calculations:

Station	2025 Annual VMT Reduction	2040 Annual VMT Reduction
Merced	4,461,250	6,250,000
Livingston	1,452,500	2,400,000
Total	5,913,750	8,650,000

	2035 Annual VMT Reduction	2035 Daily VMT Reduction
Total for Merced County (interpolated)	7,737,917	21,200
2035 VMT SCS Scenario C	6,290,124	
% Offmodel Reduction due to ACE	**0.3%**	

Assumptions:

Tier Level	Vehicle Trip Reduction (as a % of total eligible employees)	Source
Tier 1	15	AVR=1.1 baseline; AVR 1.3 control assumption. AVR = (employees on site / vehicles on site).
Tier 2	21	AVR=1.1 baseline; AVR 1.4 control assumption. AVR = (employees on site / vehicles on site).

Tier Level	Default Eligible Employee Assumption per Worksite	Source
Tier 1	175	SJVAPCD Rule 9410 Staff Report, 2009
Tier 2	490	Assumes 1342 Tier 1 and 541 Tier 2 registered worksites in the SJV and 500,000 participating employees

Tier Level	Number of Worksites	
Total	44	eTRIP Registration Data for Merced County
Tier 1	31	
Tier 2	13	

Year	Employment	
2014	69,317	CA Employment Development Department
2035	86,732	CA Employment Development Department

Year	Average HBW Trip (miles)	Source
2014	16.34	3-county model output
2035	18.95	

Work trips per employee per weekday 2

VMT Reduction Calculation:

Tier Level	Weekday VMT Reduction by Worksite (2014)	Total VMT Reduction (2014)
Tier 1	858	26,901
Tier 2	3,364	42,520
TOTAL	4,221	69,421

Projected Average Weekday 2035 VMT REDUCTION (Miles) = 100,736

2035 VMT SCS Scenario C 6,290,124

% Offmodel Reduction due to Rule 9410 1.6%

Transit, Active Transportation, and ITS GHG Reduction Analysis
Merced County
Source: Moving Cooler, 2009

2035		
Measure/Strategy	**GHG Reduction, mmt**	**% GHG Reduction**
Midpoint Active Transportation (Bicycle+Pedestrian)	6	0.357%
Midpoint Public Transit (fare, LOS, urban transit expansion)	10	0.595%
Midpoint Incident Management/Ramp Metering	6	0.357%

	Expanded Current Practice Deployment GHG Reduction in Year (mmt)				Midpoint	Midpoint (Rounded to whole # if>1)	Aggressive Deployment GHG Reduction in Year (mmt)				Maximum Deployment GHG Reduction in Year (mmt)			
Strategy Description	**2020**	**2030**	**2035**	**2050**		**2035**	**2020**	**2030**	**2035**	**2050**	**2020**	**2030**	**2035**	**2050**
Pricing Strategies														
CBD/Activity Center on-street parking	0.5	1	1	1	1	1.0	1	1	1	1	1	1	1	1
Tax/higher tax on free private parking	N/A	N/A	#VALUE!	N/A	#VALUE!	#VALUE!	0.5	1	1	1	1	1	1	1
Residentialparking permits	N/A	N/A	#VALUE!	N/A	#VALUE!	#VALUE!	0.5	1	1	1	1	2	1.8	1
Cordon Pricing	1	1	1.5	3	2	2.0	1	2	2.3	3	1	3	3	3
Congestion Pricing	5	19	19	19	27	27.0	11	35	35	35	18	43	42	39
Intercity Tolls	0.5	1	1	1	2	2.0	2	2	2	2	3	3	2.8	2
PAVD	20	19	19	19	33	33.0	39	47	46.3	44	56	63	62	59
VMT fee	8	8	7.8	7	16	16.0	25	24	23.5	22	101	97	95.3	90
Carbon Pricing (VMT impact)	11	10	10	10	20	20.0	32	31	30.3	28	136	138	136.5	132
Carbon Pricing (Fuel economy impact)	24	37	37.3	38	71	71.0	70	103	103.8	106	236	325	325	325
Land Use and Smart Growth Strategies/Nonmotorized Strategies														
Combined Land Use	1	3	4.8	10	16	16.0	7	22	27.8	45	12	38	46.8	73
Combined Pedestrian	2	2	2	2	4	4.0	5	5	5	5	6	7	6.8	6
Combined Bicycle	1	2	2	2	2	2.0	1	2	2	2	2	6	6	6
Public Transportation Strategies					0	0.0							0	
Transit Fare Measures	1	1	1	1	1	1.0	1	1	1	1	2	2	2	2
Transit Frequency/LOS/Extent	1	2	2	2	2	2.0	1	2	2.3	3	2	4	5.3	9
Urban Transit Expansion	2	4	4.8	7	7	7.0	4	7	8.3	12	8	14	17	26
Intercity Passenger Rail	1	1	1	1	1	1.0	1	1	1	1	2	2	2	2
High-Speed Passenger Rail	1	2	2.3	3	3	3.0	1	3	3.3	4	2	4	4.5	6
HOV/Carpool/Vanpool/Commute Strategies			0										0	
HOV Lanes	1	1	1	1	2	2.0	2	2	2	2	4	4	4	4
HOV Lanes (24-hour applicability)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Car-Sharing	1	1	1	1	2	2.0	2	2	2	2	5	4	4	4
Employer-Based Commute Strategies	7	7	7	7	10.4	10.0	15	14	13.8	13	35	34	33.3	31
Regulatory Measures			0										0	
Nonmotorized Zones	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Urban Parking Restrictions	0.5	1	2.5	7	4	4.0	1	4	6.3	13	3	9	11.3	18
Speed Limit Reductions	12	44	43.3	41	59	59.0	40	75	74	71	51	76	75	72
System Operations and Management Strategies														
Eco-Driving	8	18	22.5	36	29	29.0	15	29	35.3	54	38	50	53.8	65
Ramp Metering (x)	0.5	0.5	0.9	2	1	1.0	0.5	0.5	1.9	6	0.5	0.5	2.1	7
Variable Message Signs (x)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Active Traffic Management	N/A	N/A	#VALUE!	N/A	#VALUE!	#VALUE!	0.5	0.5	1.4	4	0.5	0.5	2.1	7
Integrated Corridor Management	N/A	N/A	#VALUE!	N/A	#VALUE!	#VALUE!	0.5	0.5	1.4	4	0.5	0.5	2.1	7
Incident Management (x)	0.5	0.5	1.6	5	2	2.0	0.5	1	2.5	7	0.5	1	2.8	8
Road Weather Management (x)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Signal Control Management (x)	0.5	0.5	0.5	0.5	0.6	1.0	0.5	0.5	0.6	1	0.5	0.5	1.1	3
Traveler Information (x)	0.5	0.5	0.5	0.5	0.7	1.0	0.5	0.5	0.9	2	0.5	0.5	0.9	2
Vehicle Infrastructure Integration	0.5	0.5	1.9	6	1	1.0	0.5	0.5	0.9	2	0.5	0.5	0.6	1

Source: Moving Cooler, Cambridge Systematics, 2009

Moving Cooler Baseline Emissions (mmt)*			
2020	**2030**	**2035**	**2050**
1712	1689	1680	1653

*Note 2035 is a linear interpolation between 2030 and 2050

MEMORANDUM

To: Matt Fell, Merced County Association of Governments
From: Alex Marcucci, Trinity Consultants, Inc.
Date: March 8, 2018
RE: MCAG SCS Off-Model Strategy Quantification Methodology – **Revised**

This memorandum details the quantification methodology used by Merced Association of Governments (MCAG) in evaluation of their SB 375 per capita GHG emissions target performance for the 2014 RTP/SCS (Amendment #1). This memorandum revises and supersedes the memorandum dated January 19, 2018.

In 2016, the following strategies were agreed on by the Alternative Planning Strategy (APS) Steering Committee for inclusion in the 2014 RTP Amendment #1:

- Enhanced transit strategies (transit fare reduction, urban and express transit measures);
- Passenger rail expansion;
- Active transportation strategies (bicycle lanes and walkways);
- Enhanced electric vehicle (EV) penetration (EV subsidies and charger installation);
- Rideshare strategies (carpools, vanpools, workplace TDM).

Additionally, strategies which were already included in the 2014 RTP but not quantified include:

- Intelligent Transportation Strategies and Ramp Metering.

Trinity Consultants Inc. (Trinity) was retained by MCAG to review and summarize the MCAG "off-model" quantification methodology for their SCS. The 2035 estimated level of GHG reductions quantified "off-model" or in addition to MCAG modeled GHG reduction of 5.9% is shown in Table 1 below.

Table 1: MCAG "Off-Model" GHG Emission Reductions Summary 2035 (%)

Strategy	GHG Emissions Reduction, %
	2035
Transit	0.6
Passenger Rail (ACE)	0.3
Active Transport	0.4
ITS & Ramp Metering	0.4
EVs	0.4
Rideshare/TDM	1.6
Baseline	*5.9*
Total	**10**

As shown, the MCAG SCS meets the 2035 SB 375 target of 10%. Detailed methodology estimating GHG emission benefits employed by MCAG SCS is described herein.

Transit Quantification Methodology

MCAG's 2014 RTP Amendment #1 assumes 61% higher level of rail and bus transit funding than in the 2014 RTP, due to the 2014 RTP not accounting for revenues from cap and trade and related funding sources, such as intercity rail and the low carbon transit programs. The additional transit funding will provide for more frequent headways on bus transit, fare reductions, and express transit / bus rapid transit.

In order to estimate conservative GHG emission benefits from transit strategies, MCAG assumed a "midpoint" deployment, between "expanded current practice" and "aggressive", level of GHG reductions cited in the "Moving Cooler" report by Cambridge Systematics, 2009. The "Moving Cooler" reductions in million metric tons for the appropriate transit strategies were added up and divided by the 2035 baseline GHG value, which was linearly interpolated between 2030 and 2050. The resulting percentage reduction of 0.6% was then applied to the modeled MCAG scenario GHG emissions.

Passenger Rail Commutes (ACE)

The extension of Altamont Corridor Express (ACE) passenger rail to Merced, connecting with a planned High Speed Rail station in downtown area. The ACEforward effort plans to bring at least 6 daily round trips to Merced as soon as 2025 and no later than 2027. Funding for the extension will come from a combination of cap-and-trade based sources and/or $400 million specifically identified in SB 132.

GHG emission benefits from ACE Rail expansion were quantified using ridership data from the ACEforward Draft Environmental Impact Report prepared by AECOM1. Annual VMT reductions were calculated for 2025 and 2040, the years for which ACE ridership data were available for both Livingston and downtown Merced planned stations in Merced County. Travel reductions were quantified by multiplying ACEforward ridership estimates by the distances to Merced County line from downtown Merced and Livingston (planned ACE stations) for northbound travel. To adjust for "transit dependency", an adjustment factor of 0.83 was applied consistent with ARB's GHG Quantification Methodology for the California State Transportation Agency (CalSTA) Transit and Intercity Rail Capital Program2. VMT reductions from planned Livingston and Merced station were them summed, converted to a daily estimate, and interpolated to arrive at a 2035 VMT reduction. When comparing to Merced RTP scenario VMT, this calculation approach resulted in an additional "off-model" reduction of 0.3%.

Intelligent Transportation Strategies and Ramp Metering Methodology

These strategies were already included in the 2014 RTP (pages 58-60) but were not quantified until Amendment 1. MCAG belongs to an eight-county collaborative ITS group in the San Joaquin Valley, which adopted an ITS Deployment plan in 2001, a maintenance plan in 2005, and has continued to maintain and update the ITS architecture since then. Appendix A details Merced County projects which include:

- Variable Message Signs
- Active Traffic Management
- Incident Management

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[1] See https://www.acerail.com/UploadedFiles/ACERail/0-2017-05-30/App_E_Ridership_Revenue_and_Benefits.pdf.
[2] https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/tircp_qm_16-17.pdf

- Road Weather Management (changeable message signs and advisory radios)
- Signal Control Coordination (signal synchronization in Merced, Atwater and Los Banos)
- Traveler Information

In 2009, MCAG approved the Northern San Joaquin Valley Regional Ramp Metering and High Occupancy Vehicle (HOV) Master Plan, a plan that allows and encourages the region to continue planning for these types of facilities. This plan will help guide improvements to the region's major corridors such as SR-99. Ramp metering projects will be part of the development plans for SR-99.

In order to estimate GHG emission benefits from ITS and ramp metering strategies, MCAG assumed "midpoint" deployment level of GHG reductions cited in the "Moving Cooler" report by Cambridge Systematics, 2009. The "Moving Cooler" reductions in million metric tons for the appropriate transit strategies were added up and divided by the 2035 baseline GHG value, which was linearly interpolated between 2030 and 2050. The resulting percentage reduction of 0.4% was then applied to the modeled MCAG scenario GHG emissions.

Active Transportation Quantification Methodology

MCAG complies with the San Joaquin Valley Congestion Mitigation and Air Quality (CMAQ) policy that prioritizes funding to cost-effective projects including active transportation. The CMAQ policy has been incorporated into the SIP process. Moreover, MCAG's CMAQ funding goal is to allocate 40% of CMAQ funds to active transportation. Since 2010, MCAG has provided $11.8 million of CMAQ programming to 29 active transportation projects, which is about 40% of the total CMAQ for Merced County for the period 2010 through 2020. Considering that no such formal policy exists in other California regions and the specific implementation emphasis MCAG has placed on bicycle and pedestrian projects, it is MCAG's position that the MPO is aggressive in their investment into active transportation.

Similar to analysis of transit strategies described earlier, the Cambridge Systematics' "Moving Cooler" approach was employed to quantify GHG emission reductions from active transportation projects. The "midpoint" level was used to estimate 0.3% additional GHG emissions reduction for MCAG's SCS. About a third of MCAG population resides in the City of Merced vicinity, including the University of California, Merced. The City of Merced has a complete streets policy in their General Plan adopted in 2012. The City of Merced already has a majority of its bike path /bike lane network built at one-half mile intervals per the "aggressive" level (see Figure 1 below). MCAG is developing a regional complete streets policy which will reinforce its CMAQ funding policy goal. As these active transportation strategies continue to be implemented, they would likely result in higher GHG benefits if local data could be used to estimate GHG emission benefits.

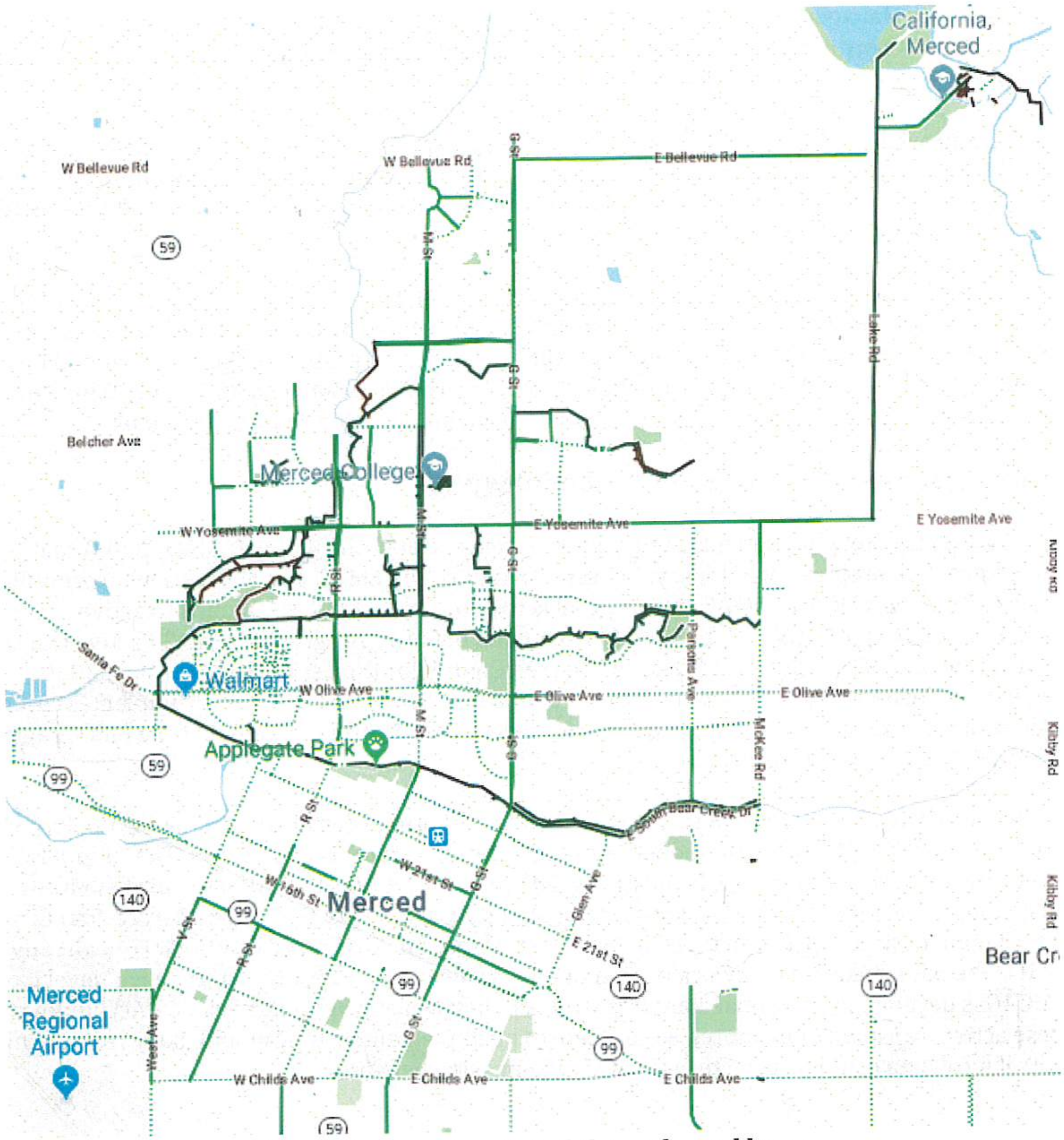

Figure 1: Merced vicinity bike paths and lanes

Electric Vehicle Quantification Methodology

MCAG is a partner with the San Joaquin Valley Air Pollution Control District, who offers the "Drive Clean!" rebate program which provides up to a $3,000 rebate to Valley residents and businesses for the purchase or lease of new, clean-air vehicles3. The program is funded through investment of local DMV registration fees. Fleet conversions for public agencies are also eligible expenditures under MCAG's CMAQ policy. In addition, MCAG is a

[3] http://valleyair.org/grants/driveclean.htm

partner with the Air District, who offers the "Charge up!" program, which provides funding for public agencies and businesses in the Valley to install electric vehicle (EV) chargers for public access. These chargers will support existing EV owners and encourage the growth of clean technology in the Valley.

MCAG participated in the Plug-in Electric Vehicle Coordinating Council (PEVCC), who published the Plug-in Vehicle Readiness Plan[4] for the San Joaquin Valley and a Guide to Siting Optimal Locations for Public Charging Stations in the San Joaquin Valley[5]. The City of Merced was determined to be one of the top ten cities in the SJV for citing Level 2 charging stations. Following the work on the Plug-in Electric Vehicle Coordinating Council, the subsequent committee, the "Valley Takes Charge" was formed to further the acceptance and use of zero and near-zero emission vehicles in the region.

In order to quantify GHG benefits from the "Drive Clean" vehicle incentive program, MCAG assumed that the state Clean Vehicle Rebate Program will expire in 2020, meaning the "Drive Clean" program is the only incentive available. Under that scenario, the benefits of the local PEV program will only be realized in 2020 through 2035. To complete the "off-model" analysis, funding data on the number and type of electric vehicles was obtained from the San Joaquin Valley Air District for 2014-2017. Vehicles were classified as pure electric (BEV) or hybrid electric (PHEV) and analyzed separately. The 2015-2017[6] average sale volumes were applied to project the number of BEVs and PHEVs that would be purchased due to the District incentive funding program for 2020 through 2035. This growth projection is a conservative estimate since it assumes the same level of funding as in 2015-2017, although District data demonstrates that program funds have increased substantially even in the first three years of the program and granted that more local funding may be available due to increase in vehicle registrations by 2035.

In order to account for vehicle attrition, light-duty vehicle survival rates from EMFAC2011 were applied to the growth projection described above. Next, the annual average CO2 emissions rate and vehicle population of light-duty gasoline vehicles were also obtained using EMFAC2011 for Merced County. The use of EMFAC2011 model was consistent with MCAG's SCS GHG emissions modeling methodology. For PHEVs, CO2 emission rates were scaled according to the ARB-reported utility factor of 0.4. Emissions per vehicle were then multiplied by the projected EV and PHEV populations for Merced in 2035. The resulting GHG emission benefits represent replacing gasoline vehicles with their PEV counterparts. GHG emissions in tons of CO2 were then divided by 2035 CO2 inventory for the MCAG SCS, which resulted in approximately 0.4% GHG reduction.

Rideshare Quantification Methodology

This strategy analyzed "off-model" includes MCAG's efforts to promote and invest in non-SOV travel options, including carpool, vanpool, and other ridesharing programs. The analysis used best available data from the San Joaquin Valley Air District's Staff Report on Rule 9410[7] (eTRIP). Rule 9410 is an employer-based commute strategy that is required of worksites in the San Joaquin Valley that have 100 or more employees. The eTRIP rule requires that employers promote and implement alternative travel options to their employees, while partner agencies must ensure service availability in their region. MCAG is a member of Calvans which provides vanpooling services to farmworkers and commuters in Merced County, as well as Dibs Smart Travel, which offers a $200 monthly vanpooling incentives.

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[4] http://valleyair.org/grants/documents/pev/6-25-14/san_joaquin_valley_siting_analysis.pdf
[5] http://valleyair.org/grants/documents/pev/6-25-14/san_joaquin_valley_pev_readiness_plan.pdf
[6] Note that 2014 was not a full funding year.
[7] http://www.valleyair.org/Programs/Rule9410TripReduction/eTRIP_main.htm

For the "off-model" analysis, all assumptions and data were based on the Air District's evaluation of GHG emission benefits during Rule 9410 implementation assessment. First, local data on the actual number of participating employers in the County of Merced was obtained. Centers were divided into two Tiers following the District's assumptions and depending on employee size. Using the District's assumed trip reduction for Tier 1 and Tier 2 employment centers and 3-county model home-based work trip lengths, GHG emission reductions were calculated for the base year of 2014, for which local data was available. Next, using Merced employment forecast and 2035 home-based work trip lengths, the reduction of 1.6% was derived.

Note that the reductions estimated in MCAG's "off-model" analysis are conservative, because they do not include all of the benefits that would be realized from Calvans and Dibs Smart Travel services that cover more than just work trips.