TECHNICAL EVALUATION OF THE GREENHOUSE GAS EMISSIONS REDUCTION QUANTIFICATION FOR THE ASSOCIATION OF BAY AREA GOVERNMENTS' AND METROPOLITAN TRANSPORTATION COMMISSION'S SB 375 SUSTAINABLE COMMUNITIES STRATEGY

April 2014

California Environmental Protection Agency

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 (ARB or Board) to accept or reject the determination of each metropolitan planning organization (MPO), that its Sustainable Communities Strategy (SCS) would, if implemented, achieve the greenhouse gas (GHG) emission reduction targets (targets) for 2020 and 2035, set by the Board in 2010. These regional targets were defined by the Board as a percent reduction in per capita GHG emissions from passenger vehicles from a base year of 2005.

On July 18, 2013, the Association of Bay Area Governments (ABAG) and the Metropolitan Transportation Commission (MTC) adopted a regional transportation plan (RTP) known as Plan Bay Area, which includes the region's first Sustainable Communities Strategy (SCS).

This technical report supports ARB's action on ABAG/MTC's SCS. It describes both the method used to review ABAG/MTC's SCS GHG quantification and the results of the technical evaluation.

The results of ARB staff's technical review were presented to the Board at a public meeting on June 27, 2013, and were based on review of ABAG/MTC's draft Plan Bay Area, published in March 2013. The RTP/SCS that was adopted in July 2013 and published in December 2013 contains minor modifications. However, these modifications do not affect the plan's ability to achieve the per capita GHG emission reduction targets, if the plan is implemented.

This report documents ARB staff's technical review of the draft plan, together with its subsequent review of the adopted Plan Bay Area, as modified. This review affirms that ABAG/MTC's adopted SCS demonstrates that, if implemented, the region will achieve a 10 percent per capita GHG emissions reduction in 2020, and a 16 percent reduction in 2035. These reductions meet the targets established for ABAG/MTC of 7 percent and 15 percent per capita GHG emissions reductions from 2005 for the years 2020 and 2035, respectively.

I. LAND USE AND TRANSPORTATION PLANNING IN THE SAN FRANCISCO BAY AREA

With a population of over seven million people, the San Francisco Bay Area (Bay Area) encompasses nine counties and 101 cities and towns. Known as much for its beautiful parks, open spaces, vineyards and other agricultural lands, as for its urban and suburban areas, the Bay Area represents about one fifth of the State's population, and about one fourth of the State's economy, as of 2011.

Several regional agencies cooperated in the preparation of the Bay Area's Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS), known as Plan Bay Area. While the legal responsibility for the SCS falls to the Association of Bay Area Governments (ABAG) and the Metropolitan Transportation Commission (MTC), the cooperation of several other agencies, including the Bay Area Air Quality Management District (BAAQMD), the Bay Conservation and Development Commission (BCDC), the county Congestion Management Agencies, local governments, local transit agencies, and local community agencies was vital to the creation of Plan Bay Area. With this extensive coordination, ABAG and MTC included well over one hundred self-governing public agencies that implement air quality and climate programs, protect and enhance the bay, build and operate transportation systems, keep traffic levels manageable, and control local land use decisions in the region.

Plan Bay Area is part of a larger initiative in the region. One Bay Area, a joint initiative of the four main regional government agencies (ABAG, MTC, BAAQMD, and BCDC), combines a variety of programs and projects with the overarching goal of protecting the environment, economy, and public health. Specifically, the One Bay Area initiatives are: Plan Bay Area, the Climate Initiatives Program, the Bay Area Prosperity Plan, a set of energy management programs, the Clean Air Plan, and the San Francisco Bay Plan. One Bay Area has been a coordinated effort since April 2010.

A. Association of Bay Area Governments

ABAG is a voluntary association formed in 1961 by elected officials from the region's cities, towns, and counties. All nine counties and 101 cities and towns within the Bay Area have chosen to be members of ABAG. For the SCS, ABAG is tasked with providing the regional forecasts on population, jobs, and housing; allocating to the nine counties in the region, the housing targets by jurisdiction and income level that the California Housing and Community Development Department (HCD) determines as the Regional Housing Needs Assessment (RHNA); and gathering and considering the available information on resource areas and farmland in the region. These efforts all support ABAG's broader task, which is to develop the region's preferred growth pattern. This was accomplished with the *Jobs-Housing Connection Strategy*, released and adopted in May 2012.

Serving as the comprehensive regional planning agency and Council of Governments in the Bay Area, ABAG is also responsible for administering the region's Priority

Development Areas (PDA) and Priority Conservation Areas (PCA) through the FOCUS Initiative created jointly in 2008 by ABAG and MTC. Other ABAG planning projects include such efforts as the Bay Trail Project, the San Francisco Estuary Partnership, the Hazardous Waste Green Business Program, and the Earthquake and Hazards Program.

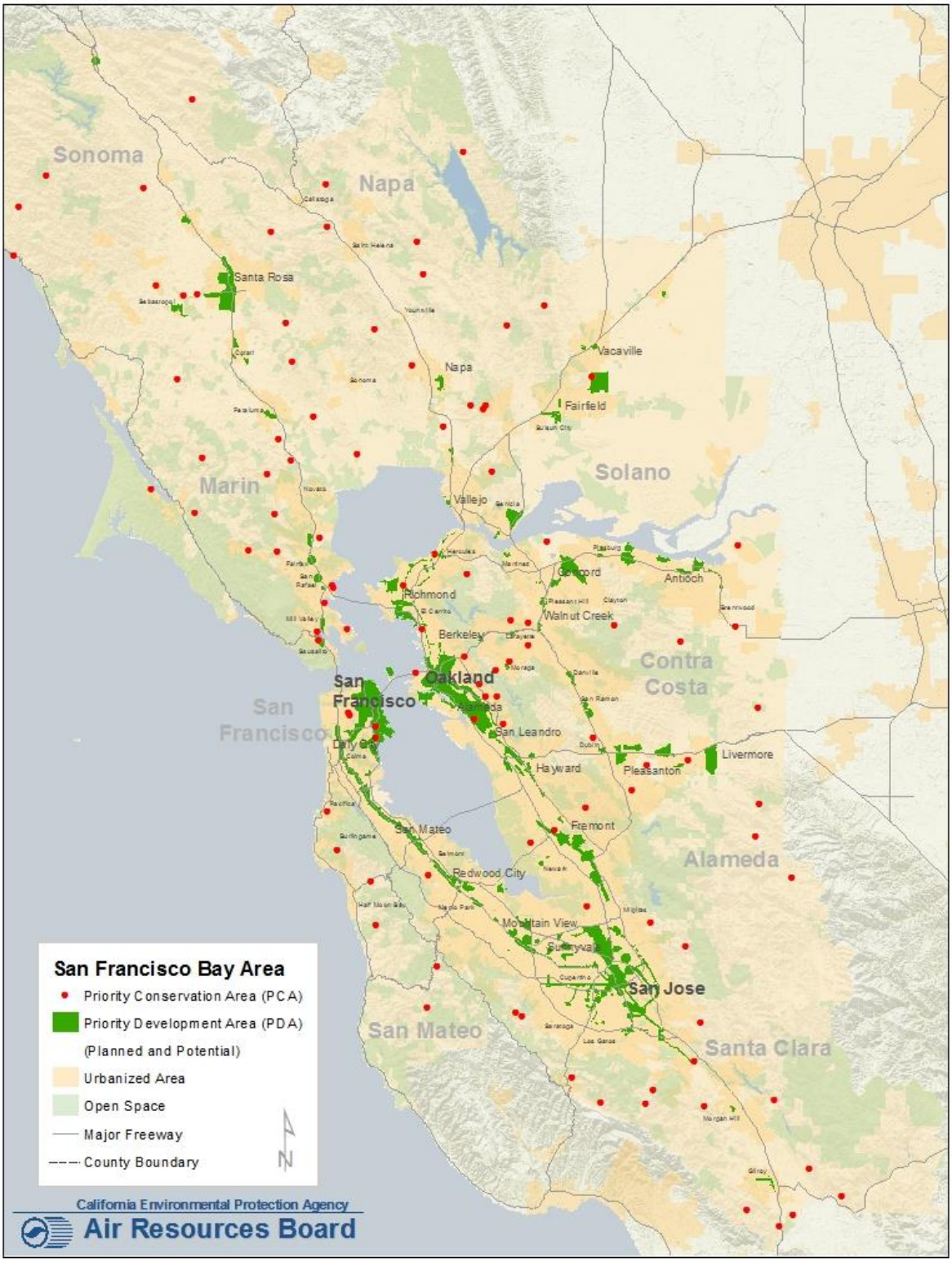
B. Metropolitan Transportation Commission

MTC was created by the State Legislature in 1970 to plan, coordinate, and provide the funding for transportation projects in the Bay Area. MTC is designated by the State as a regional transportation planning area, and by the federal government as the region's metropolitan planning organization (MPO), responsible for updating the regional transportation plan every four years. MTC is tasked with identifying the transportation network to serve the region's transportation needs, and ensuring that the RTP complies with the federal Clean Air Act (42 U.S.C. Sec. 7506), the latter of which is accomplished by coordinating with BAAQMD. In addition, both MTC and ABAG must create an integrated land use and transportation plan showing how the region could meet, if possible, the GHG targets.

1. Planning Area

The regional planning area for which ABAG and MTC are responsible is shown in Figure 1. The diverse geography of the region includes urban, suburban, and rural communities, productive agricultural lands, the Pacific Ocean coastline, and the mountains and valleys of the Pacific Coast Range.

Figure 1. ABAG and MTC Regional Planning Area



The three largest cities in the region, San Jose, San Francisco, and Oakland, currently accommodate about 30 percent of the region's total population of about 7.1 million people, and about 33 percent of the region's total jobs. The counties within which these cities reside, Santa Clara, San Francisco, and Alameda, are among the most populous counties in the Bay Area. The Peninsula region, starting in San Mateo County south of San Francisco and including a portion of northwestern Santa Clara County, consists largely of cities and suburban communities closer to the bay and rural areas nearer the coast. The South Bay includes the majority of Santa Clara County, is urban and suburban in much of its western portion, mountainous and rural in the eastern half, and is known for its high-technology industry in the "Silicon Valley." The East Bay, a highly urbanized portion of the Bay Area, consists of Contra Costa and Alameda counties, and includes the Port of Oakland, the Bay Area's largest port. The North Bay counties, Marin, Sonoma, Napa, and Solano, are generally more rural than the rest of the Bay Area, and are known for their vineyards and other working lands, as well as the natural beauty of their open spaces.

2. Regional Transportation Network

The existing transportation network serving the Bay Area is multimodal, with the great variety of transportation options arising from the region's diverse geography. That Bay Area residents value and rely upon this variety of transportation options is especially evident by observing commuters' mode share data for the San Francisco metropolitan statistical area, which is shown in *The Transport Politic*'s summary of the 2009 American Community Survey to be 14.6 percent for transit. While the Bay Area has nearly 20,000 miles of local streets and roads, 1,400 miles of highway, and eight toll bridges, there are also some-9,000 miles of bus routes, 470 miles of rail transit, five ferry operators, and just over 1,000 miles of bikeways in the Regional Bikeway Network.

Twenty-eight different highways, freeways, and expressways connect the region's local streets and roads between cities and towns in the region. Major thoroughfares include Interstate 80, which has some of the most congested travel in the region, US. Highway 101, which runs from the North Bay counties through the South Bay counties, and State Route 1, which winds along the mostly rural Pacific coast line as a two-lane highway. This highway system includes general purpose lanes, freeway-to-freeway connector lanes, auxiliary lanes, and managed lanes, including 474 lane miles of high occupancy vehicle (HOV) lanes and 14 miles of high occupancy toll (HOT) lanes, referred to locally as express lanes. During non-peak periods, these HOV and HOT lanes become general purpose lanes, resulting in a total of 4,667 lane miles of general purpose and auxiliary lanes during non-peak periods. Due to the central locations of the San Francisco and San Pablo Bays, the region also has eight toll bridges, seven

of which are state-owned and administered, operated, and maintained by the Bay Area Toll Authority, directed by MTC.

There are six rail systems that serve the Bay Area. Bay Area Rapid Transit (BART) currently runs on 104 miles of track, with 44 stations from the communities of Pittsburg and Richmond in the north to Fremont and Millbrae in the south. Caltrain carries passengers between San Francisco and Gilroy, with more than 30 stops available. The Altamont Commuter Express (ACE) operates between San Jose and Livermore in the Bay Area, and continues into the San Joaquin Valley to Stockton. Muni, run by one of the oldest public transit agencies in the U.S., provides a mix of light rail, bus, streetcar, trolley, and cable car service throughout San Francisco. Santa Clara Valley Transportation Authority provides over 25 miles of light rail service (and serves over 300 square miles of urban area with bus service throughout Santa Clara County), as well as partnering with some neighboring county transit providers to bring bus and rail service beyond Santa Clara County borders. Amtrak's Capitol Corridor trains connect the Bay Area to neighboring regions, with 170 miles of track from San Jose to Sacramento, and beyond to Auburn.

In addition to rail systems in the Bay Area, there are several other transit options for residents, visitors, and commuters from outside of the region. The Clipper® card is a fare card that can be used on most of the region's larger transit systems, and will ultimately be available for use on the approximately 20 different transit operators providing bus service throughout the region. Many of these bus systems provide connections to BART, Amtrak, other transit options, and the region's three international airports. Almost all Bay Area buses can accommodate bicycles, providing part of the solution to the "first and last mile" issue of getting people from their homes to transit stops, and from transit stops to jobsites. Bicycles are also allowed on the region's commuter ferries that operate between Vallejo, Oakland, Marin, Angel Island, San Francisco, and South San Francisco. A regional bicycle system, including the Bay Trail's 330 miles ringing the San Francisco and San Pablo Bays, and about 670 more miles of bicycle corridors, provide a means for commuters and for others who access the network for recreation and health. This regional network is envisioned to ultimately contain 2,140 miles of contiguous on-street bicycle facilities and inter-county regional paved trails to connect every incorporated town and city, and to provide access to transit systems, major activity centers, and central business districts of the region.

There are additional transit options in the region such as dial-a-ride, paratransit, employer-sponsored buses by some of the region's large employers, and interregional rail and bus services through Amtrak, the Capitol Corridor Joint Powers Authority, San Benito County Transit, Greyhound, and Megabus.

C. Policies, Laws, and Initiatives Influencing the Regional Planning Area

The Bay Area has a long history of sustainable planning, largely stemming from a region-wide value of the landscapes that characterize the region. A number of policies, initiatives, plans, and programs pre-date and form the foundation of Plan Bay Area. The development of Plan Bay Area integrated this framework into the vision and goals of the plan, relying on regional partnerships. A brief summary of the major planning initiatives, laws, and local plans that influenced that process (in addition to SB 375), and the final plan, follows.

Transportation for Livable Communities

In 1996, MTC adopted the region's first smart growth policy, the Transportation/Land Use Connection Policy. That policy established a program, termed Transportation for Livable Communities (TLC), to fund planning and capital improvements. As one of the regional tools for promoting smart growth, the TLC program allocates grants to cities, counties, and transit agencies in adherence with TLC goals. Those goals include supporting community-based transportation projects that improve downtown areas, commercial cores, neighborhoods, and transit corridors, enhancing the amenities and ambiance in such places, and making them areas where people want to live, work, and visit. In order to support the region's framework for development and conservation, as detailed below, TLC only funds projects and planning efforts located within PDAs, thus directly linking TLC to the FOCUS program. In addition to streetscape projects in high impact areas with multimodal access, TLC funds non-transportation infrastructure improvements, such as sewer upgrades, transportation demand management projects, and density incentives. Aside from funding projects, the TLC program also led to the development of streetscape design guidelines, aimed at addressing all modes of transportation. MTC evaluates project proposals based on how well they address the design guidance.

MTC Resolution 3434

In 2005, the MTC Board passed its Transit-Oriented Development Policy, entitled Resolution 3434. The policy is intended to ensure that transportation agencies, local jurisdictions, and members of the public and the private sector work together to create development patterns that are more supportive of transit by focusing on corridor and station area planning. Specifically, the resolution discusses regional transit expansion, the cost effectiveness of regional investments in new transit expansions, the Bay Area's housing shortage, the creation of new communities, and preservation of regional open space.

Focusing Our Vision (FOCUS)

Similar to the Blueprint programs of other California MPOs, the Bay Area region developed the FOCUS program in 2008 to foster smart growth and livable communities. The program is meant to provide a conservation and development strategy that

encompasses the unique nature of the region. FOCUS capitalizes on cooperation between four regional agencies to maintain and implement smart growth efforts. Spearheaded by the State-established Joint Policy Committee, which is made up of members from ABAG, MTC, BAAQMD, and BCDC, FOCUS utilizes the Joint Policy Committee as the regional planning forum. Technical assistance services are available to local jurisdictions on a competitive basis through the FOCUS program to advance transit-oriented development in PDAs. The Bay Area's Smart Growth Vision, as expressed in the Smart Growth Preamble and Policies and the Smart Growth Strategy/Regional Livability Footprint Project serves as the foundation for the development of regional smart growth policies. Through FOCUS, local governments identified a network of PDAs and PCAs, which are the central framework for the Bay Area's transportation and land use investment strategy.

Projections 2009

Biannually, ABAG publishes long-term population, housing, and employment forecasts for the nine-county region. For the first time in its 2009 forecast, entitled Projections 2009, ABAG included land use, environmental, and transportation metrics to assess the impacts of growth. These performance targets included congestion, carbon dioxide and particulate matter emissions, vehicle miles traveled, land consumption, and affordability and access. ABAG tested these potential impacts through two alternative land use scenarios. The Projections 2009 process incorporated extensive public input through 40 public workshops. The addition of performance targets, scenario alternatives, and public input on the forecasting side of regional planning helped to inform the Plan Bay Area process.

Transportation 2035: Change in Motion

In 2009, the region developed its last regional transportation plan, Transportation 2035: Change in Motion. Previous RTPs had already begun to integrate sustainability into the RTP process, but the 2009 RTP made climate change mitigation a priority as the region laid out its plans for the future transportation system. The 2009 RTP was built on a framework of performance metrics in order to assess the plan's effectiveness in meeting the goals of equity, economy, and the environment. Plan Bay Area followed that same framework and also analyzes the plan with performance targets tailored to the plan's goals and vision, which, pursuant to SB 375, must include greenhouse gas emission reduction targets.

One Bay Area Grants

The One Bay Area Grant Program (OBAG), initiated in May 2012, establishes program commitments and policies for investing about $320 million over a four year period to better integrate the region's federal transportation program with the goals of SB 375. Transportation categories such as Transportation for Livable Communities, bicycle and pedestrian improvements, local streets and roads preservation, and planning activities

are eligible for OBAG funding, along with specific funding opportunities for Safe Routes to Schools and PCAs. In order to be eligible for the funds, local jurisdictions must:

- Accept housing allocations through the Regional Housing Need Allocation (RHNA) process and produce housing using transportation dollars as incentives.
- Adopt a Complete Streets Policy Resolution in addition to meeting MTC's complete streets policy.

II. ABAG AND MTC'S SUSTAINABLE COMMUNITIES STRATEGY

Development of ABAG/MTC's Plan Bay Area began in 2010, with the evaluation and eventual selection of performance targets for use in assessing and comparing alternative strategies with a consistent set of metrics. Early in the process, ABAG/MTC collected the necessary data on current and future regional population, housing, and employment for use in developing forecasts. The base year for Plan Bay Area is 2010 and the horizon year is 2040. This chapter summarizes the key land use and transportation assumptions, GHG emission reduction performance results, and plan development features of ABAG/MTC's adopted RTP/SCS.

A. Land Use

Development of Plan Bay Area's land use approach was initiated by evaluating a variety of land use scenarios that distributed the forecasted growth to specific locations. These scenarios sought to address the needs and aspirations of each Bay Area jurisdiction, as identified in locally adopted general plans and zoning ordinances, while meeting performance targets approved by the regional agencies to guide and measure the region's future growth. The performance targets will be discussed further in Section D. In the development of the preferred land use scenario, the plan sought to achieve four objectives:

- Create a network of complete communities where transit, jobs, schools, services and recreation are located near homes
- Increase the accessibility, affordability, and diversity of housing in order to attract the businesses and talented workforce needed for a robust future economy
- Create jobs in order to maintain and expand a prosperous and equitable regional economy by building on the existing concentration of knowledge-based and technology industries in the region
- Protect the region's unique natural environment of agricultural, natural resource, and open space lands that contribute to residents' quality of life

After a public process and scenario modeling efforts, the preferred land use scenario was selected out of five alternatives. The preferred scenario focuses growth in locally nominated PDAs while preserving land in the PCAs, resulting in the accommodation of

all of the region's growth within five percent of the region's land. By pairing this development pattern with the transportation investments and policies, the region's land use and transportation planning processes were explicitly integrated for the first time.

PDAs are existing neighborhoods chosen by local jurisdictions as appropriate places to concentrate future growth. The region has identified nearly 200 PDAs. These neighborhoods must be served by at least one transit stop or station, be supported by local plans to provide a wider range of housing options, and include amenities and services to meet the day-to-day needs of residents in a pedestrian-friendly environment. Once a community is established as a PDA, the local jurisdiction assigns the PDA one of five Place Type categorizations. Those Place Type categorizations—regional center, city center, suburban center, transit town center, or rural center—guide the character, scale, and density of future growth. In addition to accommodating growth, PDAs help move the region away from a piecemeal approach to development.

It is important to distinguish between the ABAG/MTC-developed term "PDA" and the related concept of Transit Priority Projects (TPP) first defined in SB 375. TPPs, in addition to other provisions, are projects within one-half mile of a major transit stop or high-quality transit corridor included in a regional transportation plan. The difference between these two terms is largely in the geographic nature of the PDA and the project-level specificity of TPPs. In other words, PDAs define a geographic area with some guidelines and streetscapes, while TPPs define the criteria of projects within a geographic area in relation to transit availability for the purposes of CEQA streamlining. In Plan Bay Area, TPPs cover a larger portion of the region and are more tightly focused on transit accessibility than the PDA concept. Figure 2 shows PDAs, TPPs, and areas of overlap within the Bay Area.

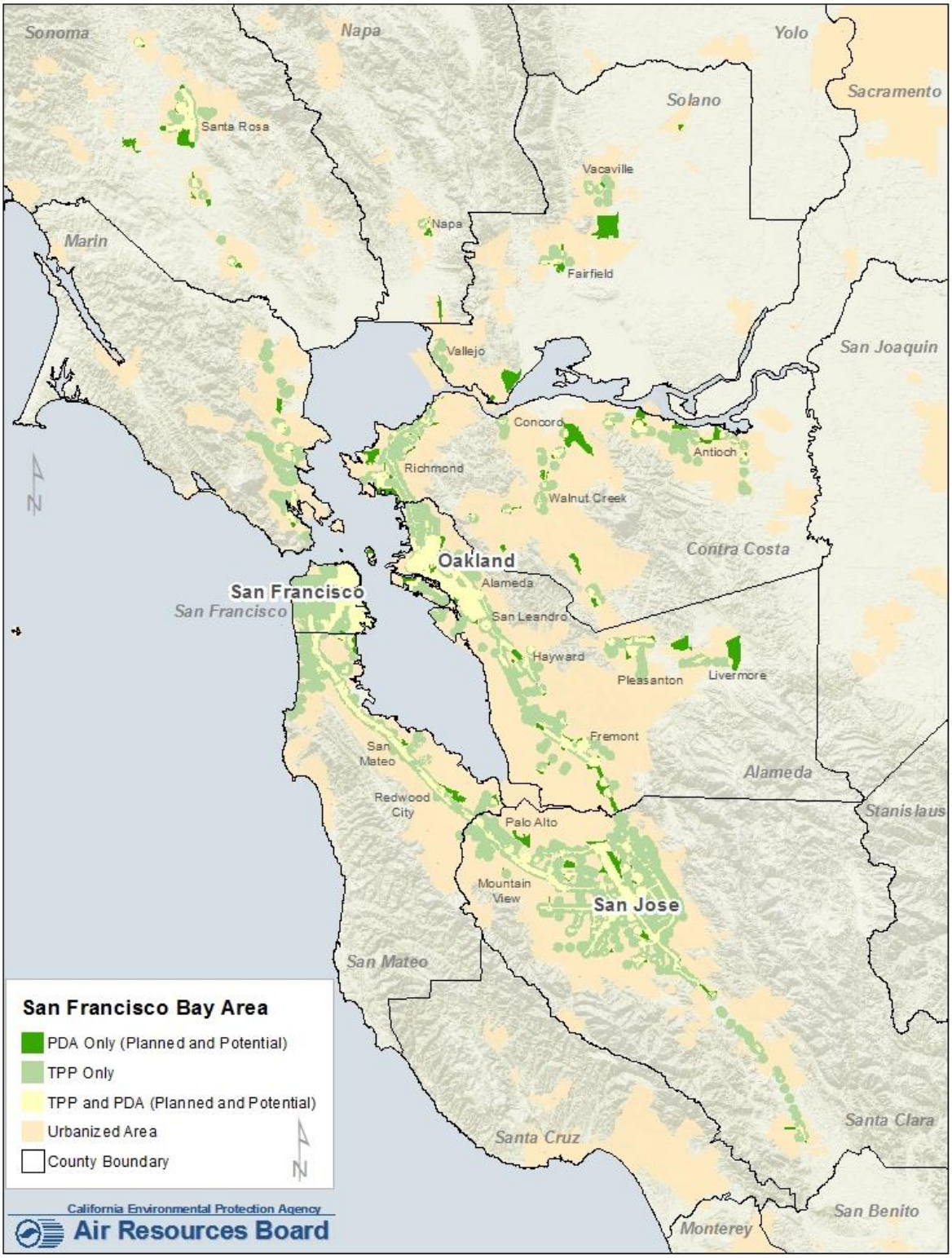
Priority Development Areas

- Locally-supported infill areas within existing communities
- Near existing or planned fixed transit or comparable bus service
- Where there is local commitment to develop more housing, amenities, services

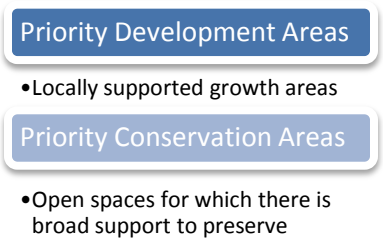
Transit Priority Projects

- Within ½ mile of major transit stop or high-quality transit corridor included in an RTP
- At least 50% residential use
- Minimum net density of 20 units per acre
- At least a 0.75 floor-area ratio for the commercial portion of the project

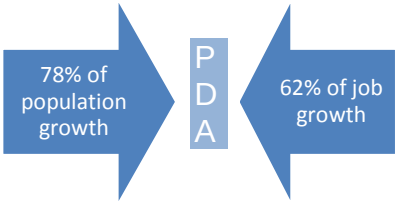
Figure 2. Priority Development Areas and Transit Priority Projects in the Bay Area



To complement the Priority Development concept, PCAs are regionally significant open spaces for which there exists a broad consensus for long-term protection, but which also face development pressure in the near term. PCAs play a central role in ensuring that Plan Bay Area incorporates the protection of farmland and resource areas. For many North Bay communities, PCAs are meant to help preserve the character and the economy of those communities.



The framework of PCAs and PDAs allows the plan to meet all of the region's growth in a manner consistent with the region's land use goals and market demands. In addition to meeting the California Housing Element law's requirement (Chapter 3, Article 10.6 of the California Government Code) that each jurisdiction plan for housing at all income levels, Plan Bay Area allocates all of that growth within existing urban growth boundaries or urban limit lines. For example, the plan results in a shift in the share of multi-family and single family housing units in the region. Of the region's new housing, about 70 percent of those new units are forecast to be developed as multi-family housing and about 30 percent as single-family housing. PDAs are planned to accept 78 percent of the region's population growth and 62 percent of the job growth. The cities that are anticipated to experience the greatest increase in the number of new housing units are San Jose, San Francisco, Oakland, Sunnyvale, and Concord, all of which are cities with multiple PDAs. The top five cities in terms of absolute job growth are San Francisco, San Jose, Oakland, Santa Clara, and Fremont, in descending order.



The One Bay Area Grant program will support the PDA and PCA framework.

B. Transportation

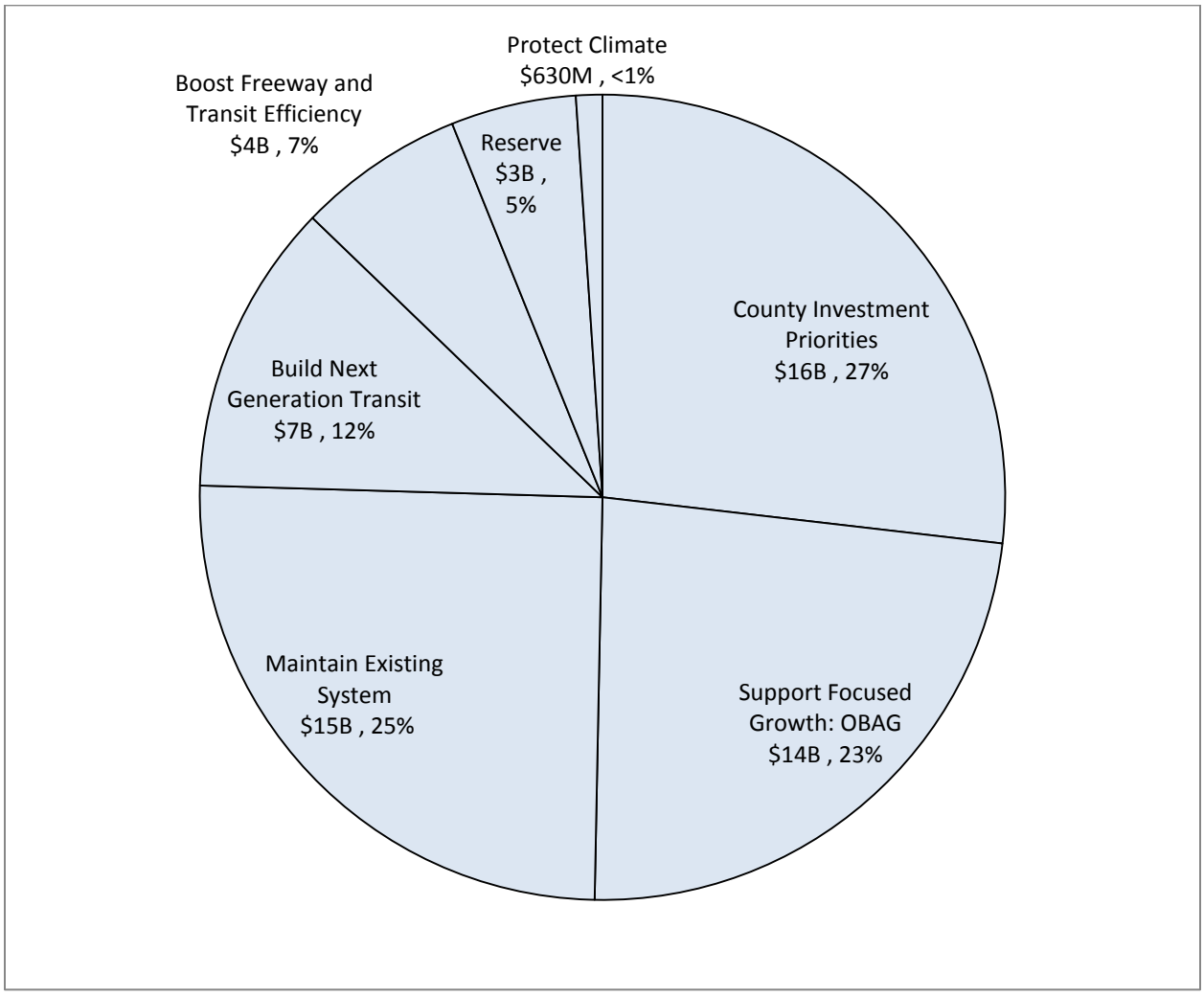
Plan Bay Area structures its transportation investment plan to support the region's long-term land use strategy. To support growth in existing Bay Area communities, the plan continues to support a "fix it first" emphasis, by investing the majority of funds to maintain and boost efficiency of the region's existing transit and roadway system. This was also an emphasis in the 2009 regional transportation plan. The plan also continues to support focused growth in the PDAs, with strategic investments in major new transit projects and with its new One Bay Area Grant program.

Transportation investments in the plan total $292 billion over a 28-year period. Of the total, about 80 percent, or $232 billion, were previously committed for specific projects through existing sales tax measure expenditure plans or State Transportation Improvement Program (STIP) funds. The remaining 20 percent, or $60 billion,

are discretionary funds used to support six transportation strategies:1) maintain the existing transportation system; 2) support focused growth; 3) build next-generation transit; 4) boost freeway and transit efficiency; 5) county investment priorities; and 6) climate initiatives.

The chart below summarizes the discretionary revenue investment levels assumed in the plan, by transportation strategy:

Figure 3. Plan Bay Area Transportation Strategy Investment Summary Discretionary Funds (Total $60 Billion)



Below is a summary of key projects and programs funded under each investment strategy. More detail on Plan Bay Area funded projects and programs is available in the Plan Bay Area Online Project Database (http://rtp.mtc.ca.gov/2040/).

Maintaining the Existing Transportation System

Approximately 87 percent of total plan funding goes toward sustaining the region's existing system. This includes investments in operating and maintaining the transit system, local streets and roads, bridges, and highways. For example, approximately $13 billion in discretionary funds are slated for transit operating and capital needs, $800 million for enhancing the region's current lifeline transit operating program, and another $10 billion in OBAG discretionary funds are dedicated to maintaining the region's existing pavement condition on local streets and roads. The relatively large percentage of discretionary funding and committed revenues directed towards maintenance of the existing transportation system are identified as necessary because the age of the Bay Area's transportation system (among the oldest in the state) requires more funding to maintain, renovate, and replace, and includes more rail services, which require more capital funding than other modes.

Support Focused Growth

To encourage more development near high-quality transit and to reward jurisdictions that produce housing and jobs, Plan Bay Area includes $14.6 billion in discretionary funds for targeted transportation investments in PDAs and support for PCAs. These monies will be administered through the region's One Bay Area Grant (OBAG) program. The OBAG program allows communities flexibility to invest in transportation infrastructure to support infill development, bicycle and pedestrian improvements, local street repair, planning, Safe Routes to Schools, and PCAs. OBAG is a locally administered funding program, guided by county-specific PDA Investment and Growth Strategies, developed by congestion management agencies. To be eligible for OBAG funding, jurisdictions must adopt complete streets policies, and planning and zoning policies that meet the requirements from the Regional Housing Need Allocation (RHNA) process.

Build Next-Generation Transit

Plan Bay Area also identifies significant future transit investments, including improvements to the region's core transit systems, ten new bus rapid transit projects in San Francisco, Oakland, and the South Bay region, rail extensions that support and rely on high levels of future housing and employment growth, and an early investment strategy for high-speed rail in the Peninsula corridor. This category adds $7 billion or 12 percent of total discretionary plan funds to existing investment commitments for transit.

Boost Freeway and Transit Efficiency

The plan also invests an additional $4 billion or 7 percent of discretionary plan funds into boosting the efficiency of the region's existing highway and transit networks. These dollars help support the Freeway Performance Initiative and the Transit Performance Initiative. Both programs aim to use low-cost technology upgrades to improve the

speed and reliability of roadways and transit service. Technology investments include: ramp metering, traffic cameras, changeable message signs, traffic signal coordination, transit signal priority, and incident and emergency management. In addition, investments are also made to support implementation of San Francisco's congestion pricing projects, as well as construction of the Regional Express Lane network in Solano, Contra Costa, and Alameda counties.

County Investment Priorities

More than a quarter of the plan's discretionary funds, or $16 billion, is used to fund key local transportation priorities, identified in county transportation plans prepared by the region's congestion management agencies. These projects complement a number of the regional discretionary investment strategies described above, helping to maintain the existing roadway and transit systems, as well as helping to fund county complete street programs, which deliver substantial bicycle and pedestrian improvements to the region.

Climate Initiatives

Plan Bay Area invests $630 million in the following eight climate initiative programs to support further reduction of greenhouse gas emissions in the region: a clean vehicles feebate program, vehicle buyback and plug-in electric vehicle purchase incentives, construction of a regional electric vehicle charger network, smart-driving education campaign, expansion of car-sharing services, vanpool incentives, a commuter benefit ordinance, and climate initiative innovative grants. Each program is described further in the next section.

C. Climate Initiatives

Below is a summary of the climate initiative programs identified in Plan Bay Area.

Clean Vehicles Feebate Program

Plan Bay Area invests $25 million to establish a regional feebate program. The program is intended to be revenue neutral and incentivize the purchase of more fuel-efficient vehicles by charging a one-time point of purchase fee to consumers purchasing less GHG efficient vehicles, and using the fee to provide rebates to those purchasing more GHG efficient vehicles.

Vehicle Buy-Back/Purchase Incentive Program for Plug-In Electric Vehicles

The new regional vehicle buyback program is intended to accelerate fleet turnover in the region toward more advanced and efficient plug-in hybrid electric or battery electric vehicles (PHEVs or BEVs), by inducing demand among consumers who might otherwise either delay car purchasing, or buy a new or used conventional vehicle. To do this, the program will offer consumers willing to trade in older, less efficient

vehicles, cash incentives toward the purchase of a new PHEV or BEV. The less efficient cars will be retired from service. Cash incentive amounts are expected to vary with the fuel economy of the vehicle being traded in, as well as the vehicle type being purchased. Plan Bay Area sets a total of $120 million aside for this voluntary incentive program.

Regional Electric Vehicle Charger Network

The objective of the new regional charger program is to establish a regional public network of electric vehicle supply equipment (EVSE) for PHEVs, allowing drivers to increase use of a vehicle's all-electric range. Miles traveled using electricity exclusively will yield larger GHG benefits than using these vehicles in the gasoline-powered mode. To achieve this, the program helps overcome some of the cost barriers to EVSE installation, by providing financial assistance to interested employers, retailers, parking management companies, and others, for EVSE installation at workplaces, commuter hubs, and other destinations. Plan Bay Area allocates $80 million to install more EV chargers in the Bay Area.

Smart Driving Strategy

The smart driving strategy program will be a public education campaign for the region's motorists to encourage driving styles and vehicle maintenance that save fuel and reduce vehicle emissions. The program will also provide rebates for in-vehicle, real-time fuel efficiency gauges. Plan Bay Area provides $160 million for the program and targets emission reductions from the existing stock of vehicles not likely to be retired and replaced by a zero emission vehicle in the near future.

Car Sharing

Plan Bay Area invests $13 million to expand car sharing services in the region, with the goals of ensuring that vehicles are available at high-demand locations, and expanding services in the region's suburban communities. Car sharing services allow people to rent cars by the hour, resulting, according to some studies, in reduced vehicle ownership and vehicle travel.

Vanpool Incentives

The plan invests $6 million to enhance the region's existing vanpool program, by reducing the cost of van rentals thereby encouraging greater participation. Vanpools help to remove personal cars from commutes that are not well served by transit, and help reduce overall emissions.

Commuter Benefit Ordinance

The Bay Area Air Quality Management District and MTC will work jointly to adopt a regional commuter benefit ordinance as a means to reduce GHG emissions.

The ordinance would help reduce emissions by requiring employers with 50 or more full-time Bay Area employees to offer incentives for their employees to use a mode other than driving alone while commuting to and from work.

Climate Initiatives Innovative Grants

In its previous RTP, Transportation 2035, MTC invested $33 million in a Climate Initiatives Innovative Grant program to reduce GHG emissions from the transportation sector and included efforts such as Safe Routes to Schools, transportation demand management, and other creative ideas. Given that many of the pilot projects funded in that program show promise in continuing to reduce GHG emissions from the transportation sector, Plan Bay Area has set aside $226 million to expand on this program and the successful strategies it has identified.

D. GHG and Other Outcomes

Building on the Bay Area's history of regional partnership to meet sustainability goals, the plan projects a 10 percent regional reduction of per capita GHG emissions from 2005 levels in the year 2020, and a 16 percent reduction in the year 2035. It does so while also meeting the requirement to accommodate the housing needs of the region's projected population growth. The decline in per capita GHG emissions results from efforts to increase the efficiency of the existing transportation system, to meet the housing demands for the region's changing demographics through transit-oriented development, and to pursue climate initiatives.

ABAG/MTC has appropriately not included in its greenhouse gas emissions reduction figures any GHG emissions reductions from the ARB-adopted technology and fuel programs, such as the Low Carbon Fuel Standard or the Advanced Clean Cars program. This is because the regional targets adopted by ARB in 2010 do not include reductions from these statewide technology and fuel programs, but rather focus on reductions from strategies implemented at the regional and local levels.

In addition to meeting the ARB-established targets for GHGs and the SB 375 planning regulations for housing, Plan Bay Area is meant to help the region achieve a number of other goals. Plan Bay Area also lays out voluntary performance targets for a number of different metrics of significance to the region's residents. These voluntary performance targets address particulate air pollution, active transport, housing, open space and agricultural land, social equity, economic vitality, transportation system effectiveness, and safety.

Plan Bay Area outlines 13 voluntary performance targets in addition to the two statutorily required targets for GHGs and housing. On seven of these voluntary performance targets, the plan either exceeds, achieves, or moves in the right direction. For example, one performance target aims to reduce exposure to fine particulate matter, and another looks at reducing coarse particulate emissions. The plan exceeds the fine particulate matter performance target, which will help the Bay Area maintain its

federal attainment status for this pollutant. The plan makes progress towards the coarse particulate matter performance target, though the region is still not in attainment for this pollutant. Plan Bay Area addresses another public health-related target with an increase in average daily time walking or biking per person for transportation.

The plan loses ground against some of the voluntary transportation system and access performance targets. For instance, the share of household income needed to cover transportation and housing costs rises to 69 percent from 56 percent for low-income and lower-middle income residents during the planning period. Also, the distressed state highway lane-miles will increase to 44 percent of the regional highway system by 2040. Lastly, the share of transit assets past their useful life is projected to increase to 24 percent of all transit assets.

Plan Bay Area considered social equity in the plan evaluation, through the voluntary performance targets, but also through the completion of an equity analysis. The equity analysis evaluated the projected outcomes of the plan for communities of concern. Based on public input, ABAG/MTC define communities of concern as neighborhoods with high concentrations of four or more of the following factors: minority persons, low-income individuals, persons who are Limited English Proficient, seniors age 75 and over, persons with disabilities, households without cars, single-parent households, and renters paying more than 50 percent of household income on rent.

ABAG/MTC used five equity performance measures to conduct its equity analysis. The results of the equity analysis show that, relative to a 2010 baseline, neither the communities of concern, nor the region as a whole show improvement for each of the equity performance measures. The equity analysis highlights key challenges in the areas of housing displacement due to rising land values, increased travel times for communities of concern, and health and safety concerns due to increased vehicle traffic within communities of concern. The plan responds with an increased emphasis on funding to support the provision of affordable housing, requirements for the adoption of local housing elements in order to receive strategic funding, and conditions that PDA Investment and Growth Strategies examine housing policy issues.

E. Public Outreach Process

ABAG/MTC developed Plan Bay Area with extensive input from the region's diverse stakeholders through a collaborative approach. Starting in 2008, ABAG/MTC created a regional initiative, FOCUS, which linked local community development goals with the regional planning process through voluntary efforts. With FOCUS as a foundation, ABAG/MTC launched an effort in February 2011 to bring together stakeholders for the development of Plan Bay Area. Specifically, business groups, environmental organizations, equity organizations, and community-based organizations all voiced their input in the process through public workshops, telephone surveys, online surveys, focus group meetings, and workgroup meetings. Local governments were also involved throughout the process. In addition, the BAAQMD, the BCDC, and three dozen of the region's transportation partners, provided the more regional perspective. Based on their

contributions, as well as multiple rounds of local and partner agency input and review ABAG/MTC released the draft Plan Bay Area in March 2013. The public was invited to provide comments on the draft Plan Bay Area from March 22, 2013 until May 16, 2013.

Public engagement at this stage took the form of three rounds of public workshops throughout the planning process. In total, twelve public workshops took place across the region with over 1,250 residents in attendance. In addition, three telephone polls gathered input from hundreds of the region's residents. ABAG/MTC provided a number of online options for participation, namely, the One Bay Area website, which received over 250,000 hits, and a virtual public workshop, which garnered 1,300 participants. The draft Environmental Impact Report (DEIR) also offered an opportunity for the public to provide input into Plan Bay Area, with formal commenting open during the 45-day comment period from April 2, 2013 until May 16, 2013. Public comments received on the DEIR and the draft Plan Bay Area addressed a variety of issues, but many stakeholders focused on how the Bay Area could better incorporate housing affordability, robust transit options, anti-displacement measures, and jobs/housing balance. Over 550 comment letters were submitted on the DEIR and draft Plan Bay Area by implementing agencies, various stakeholder organizations, and individuals.

F. Plan Implementation

Plan Bay Area outlines the vision and goals for planning the region's growth in the coming twenty-eight years and provides steps and strategies to support plan implementation. These strategies address challenges in transportation financing, affordable housing, governance, climate adaptation, natural disasters, and economic analysis. Because of their land use authority, local governments will also play an essential role in implementing Plan Bay Area.

ABAG/MTC aims to meet these challenges through advocacy, implementation of best practices, public education campaigns, grant programs, and partnerships. For example, Plan Bay Area highlights an existing partnership between MTC, ABAG, BCDC, Caltrans, National Oceanic Atmospheric Administration's Coastal Service Center, and Bay Area communities to increase preparedness and resilience to sea level rise while protecting vital ecosystem and community services. These partners are compiling a comprehensive inventory of potentially vulnerable transportation assets along a section of the Alameda County shoreline and will relate the vulnerability of these assets to the rest of the region's transportation network.

In the plan's advocacy issues platform, five out of six issues relate to the financial tools necessary to fund the housing, infrastructure, and transportation goals in Plan Bay Area. This suggests that successful implementation of Plan Bay Area will require serious attention to transportation finances from all levels of government. For example, the Plan Bay Area advocacy issues platform outlines the necessity of strongly supporting legislative changes to lower the voter threshold for local and regional transportation tax measures from two-thirds to 55 percent. The current voter approval threshold for local self-help taxes is described as missed opportunities for local taxes to

support the cost of the region's future transportation needs. Another strategy outlined as necessary to support plan implementation includes ABAG/MTC urging the passage of State legislation to create a permanent revenue source for transportation in a manner consistent with the region's "fix it first" policy. Such legislation, Plan Bay Area describes, would be essential to maintaining the existing local and state transportation network.

Local governments will be critical to the success of Plan Bay Area at reducing GHG emissions from passenger vehicle activity. Many of the region's local governments are voluntarily adopting GHG emission reduction strategies, primarily through their local climate action planning efforts and general plan update processes. Over thirty local governments in the region have thus far adopted climate action plans and many have updated or amended their general plans to incorporate sustainable communities planning into the circulation, land use, housing, and other elements.

III. ARB STAFF REVIEW

The Sustainable Communities and Climate Protection Act of 2008 calls for ARB's "acceptance or rejection of the MPO's determination that the Sustainable Communities Strategy would, if implemented, achieve the greenhouse gas emission reduction targets" in 2020 and 2035. ABAG/MTC's quantification of GHG emissions reductions in the SCS is central to its determination that the SCS would meet the targets ARB established in September 2010.

As required by Government Code section 65080(b)(2)(J)(i), ABAG/MTC submitted a quantification methodology to ARB on December 1, 2010. For the technical foundation of the RTP/SCS GHG quantification, the methodology identifies MTC's travel modeling system, growth and land use forecast, and transportation project assumptions. Using this methodology, ABAG/MTC estimated that Plan Bay Area would achieve a 10 percent per capita reduction in GHG emissions from passenger vehicles by 2020, and a 16 percent per capita reduction by 2035.

ARB staff prepared the following analyses based on the draft Plan Bay Area and GHG quantification, released in March 2013, then reviewed changes made for the final Plan Bay Area, released in December 2013, that affect the GHG quantification. Staff's analyses show that if implemented, ABAG/MTC's SCS would meet the targets set by the Board for 2020 and 2035. ABAG/MTC followed advanced modeling practices using an activity-based model and used reasonable model inputs and assumptions. In addition, plan performance indicators are supportive of estimated GHG reductions.

A. Application of ARB Staff Review Methodology

ARB staff's review of ABAG/MTC's SCS focused on the technical aspects of regional modeling that underlie the quantification of GHG reductions. The review is structured to examine ABAG/MTC's modeling tools, model inputs, application of the model, and modeling results, following the general method described in ARB'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 the region and its modeling system, ARB staff tailored and expanded the general methodology to be applicable for ABAG/MTC's SCS.

ARB staff evaluated how ABAG/MTC's models operate and perform in estimating travel demand, land use impacts, and future growth, and how well they provide for quantification of GHG emissions reductions associated with the SCS. ARB staff also evaluated the climate policy initiatives that MTC developed as part of Plan Bay Area. In evaluating whether ABAG/MTC's GHG quantification is reasonable for some of the region's chosen strategies, ARB staff examined issues such as:

- How the growth forecast reflected the economic recession
- The basis for allocating land use changes
- How well MTC's activity-based model replicated observed results

- How MTC applied off-model tools in estimating the benefits of climate policy initiatives
- MTC's model sensitivity to changes in key land use and transportation variables as compared with the empirical literature

To help answer these and other questions, ARB staff used publicly available information in Plan Bay Area, accompanying documentation including technical appendices, and the model calibration and validation reports. ABAG/MTC also provided additional clarifying information, and a data table, as shown in Appendix A.

In order to assess the technical soundness and general accuracy of ABAG/MTC's GHG emission reduction quantification, four central components of ABAG/MTC's GHG analysis were evaluated, including: modeling tools, data inputs and assumptions for the modeling tools, model sensitivity analyses, and performance indicators.

Data Inputs and Assumptions for Modeling Tools

ARB staff evaluated ABAG/MTC's key model inputs including the underlying data sources and assumptions to confirm that they represented current and reliable data for use in the model. This involved using publicly available, authoritative sources of information, such as national and statewide survey data on socioeconomic and travel factors. A subset of the most relevant model inputs for GHG quantification includes: 1) regional socioeconomic characteristics, 2) the region's transportation network, 3) travel inputs, and 4) cost assumptions. The documentation of region-specific forecasting processes and approaches, especially where applicable to the evaluation of the region's land use forecast assumptions, were also evaluated.

Modeling Tools

ARB staff reviewed MTC's travel demand model (TDM) to assess how well the modeled outputs estimated based on socioeconomic, land use, and travel data inputs and assumptions used to model the SCS replicates observed results. In addition, ARB staff evaluated MTC's off-model documentation and results to gauge whether MTC used appropriate methodologies to quantify the expected reduction in GHG emissions from some of the strategies in the SCS. ARB staff also considered MTC's modeling practices in light of the California Transportation Commission's (CTC) "2010 California Regional Transportation Plan Guidelines," the Federal Highway Administration's (FHWA) "Model Validation and Reasonableness Checking Manual," and other key modeling guidance and reference documents.

Regional Performance Indicators

Performance indicators help to explain changes in VMT and related GHG emissions that are expected to occur, whether through changes in travel modes, vehicle trip distances, or some other means. ABAG/MTC developed several performance

indicators to evaluate the effect of implementing Plan Bay Area. ARB staff conducted a qualitative evaluation to determine if increases or decreases in these individual indicators are directionally consistent with ABAG/MTC's modeled GHG emissions reductions. In particular, the following performance indicators were evaluated: residential and employment density, housing types, housing units in PDAs, passenger VMT, mode share, and change in average trip length.

B. Data Inputs and Assumptions for Modeling Tools

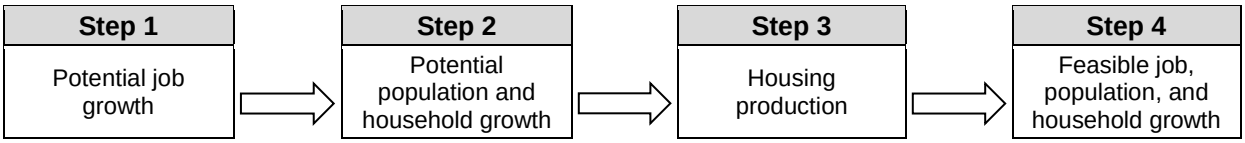
Plan Bay Area is based on a number of significant inputs and assumptions, which influence many of the strategies relevant to GHG emissions reductions. These inputs and assumptions provide the foundation for ABAG/MTC's modeling approach, and are used by MTC's travel model to project changes in the land use and transportation systems. Inputs and assumptions include land use attributes, socioeconomic and transportation network characteristics, and auto operating costs. ARB staff evaluated the appropriateness of the data on which these inputs and assumptions are based.

1. Demographics and the Regional Growth Forecast

ABAG/MTC forecasts growth of the region's population and economy to inform assumptions about how many people will live in the region by 2035, how many households they will form, the number and types of available jobs those people will have, and where they will live. ABAG/MTC attempts to project growth and future land use distribution to guide investments and policies of the nine county region.

ABAG/MTC's growth forecast is based on employment, population, and housing assumptions throughout the year 2040. ABAG/MTC first estimates the potential for job growth for the Bay Area as a share of the U.S. Bureau of Labor Statistics' national growth projections. This estimation is meant to reflect the difference between national and regional labor force participation in 2010 among various economic sectors, such as the professional services and retail sectors. ABAG/MTC determined the population, number of households, and household income levels using their analysis of the initial job growth forecast, labor force participation rates, and the number of persons per household. ABAG/MTC then derived labor force, total population and total households. The third step calculates the regional housing production. This estimation is based on past housing production levels, projected household income, and new policies and programs to support housing production in the Priority Development Areas (PDAs). Since future housing production limitations may influence the number of workforce households that can be accommodated within the region, job, population, and household forecasts were adjusted during the final step. ABAG/MTC's forecast process is shown in Figure 4.

Figure 4. ABAG/MTC's Process to Develop Demographic Forecast



ABAG/MTC's Growth Forecast

ABAG/MTC's growth forecast was prepared by the Center for Continuing Study of the California Economy (CCSCE). Based on the national employment growth by major industry sectors and the region's share of that growth, the projection assumes that the MPO region remains attractive to a diverse and highly specialized labor force in the future. Regardless, potential constraints to the region's economic competitiveness, such as higher housing costs close to employment centers, funding cuts, and an aging infrastructure throughout the region were considered during the forecast process. Much of the region's recent economic growth has been supported by the development of "greenfield" or undeveloped land. These new development areas accommodated substantial new housing, with expanded infrastructure and services, while many of the older cities face physical, market, and regulatory constraints to large-scale housing production. ABAG/MTC assumes that the region's most concentrated job centers will continue to be located in the major central business districts, downtowns, and transit corridors throughout the Bay Area. However, commuter travel time and travel costs may increase and could result in growing congestion in the larger business centers, highways, and freeways.

ABAG/MTC, however, endeavors to concentrate housing and job growth in the region's core, reversing historical trends of the housing and job dispersal. Encouraging infill development, improving the infrastructure, and creating supportive policies, new investments, and sustainable development patterns are intended to support those endeavors. ABAG/MTC expects strong growth in key industries in technology and related sectors within the MPO's larger cities and industrial centers, such as San Francisco and Silicon Valley.

Based on historical housing production data within the Bay Area, ABAG/MTC estimates an additional 660,000 housing units, or an annual average of approximately 22,000, to be constructed between 2010 and 2040. ABAG/MTC recognizes, to accommodate this amount of new housing units within the major districts, city centers, and downtowns, the share of multi-family housing must increase.

ABAG/MTC's approach to forecasting assumes that job growth is the driving force behind regional population and household growth. ABAG/MTC used a number of state and national data sources, such as the California Department of Finance (DOF) and the U.S. Census Bureau, to develop assumptions about the population profile, the number

of employees per household, the labor force participation rate, the vacancy rate, and other variables. Based on those assumptions, and given the estimated number of new housing units that could be constructed, ABAG/MTC then derived the number of jobs that the region could support. ABAG/MTC's growth projections are summarized in Table 1.

Table 1. ABAG/MTC's Employment, Housing, and Population Projection

Demographics	2010	2020	2035	2040
Employment	3,385,000	3,987,000	4,347,000	4,505,000
Housing Units	2,786,000	2,956,000	3,321,000	3,446,000
Population	7,091,000	7,718,000	8,795,000	9,299,000

The demographic inputs and assumptions ABAG/MTC used in establishing its growth forecast describe a number of key characteristics of the future population living and working in the Bay Area. These data inputs and assumptions were developed through ABAG/MTC's forecast process, described above. External consultants from CCSCE, UC Berkeley, and Strategic Economics validated the final forecast for the Bay Area region. ARB staff focused its review on the employment, housing, and population inputs to the model through the year 2035.

Employment

Employment describes the total number of workers in a region, which in turn, influences travel patterns. Furthermore, employment relates to the number of generated commute trips. Estimating the amount and the reasonable distribution of employment within a geographically constrained region is therefore the key element in ABAG/MTC's growth forecast. ABAG/MTC used a number of recognized and accepted data sources in developing its employment forecasts, including historic employment data from the Employment Development Department (EDD), the U.S. Census Bureau, the American Community Survey (ACS), and the sector forecast model from Caltrans.

To establish employment levels for the 2010 base year, employment was based on total jobs by sector and was also derived from California EDD wage and salary job estimates. Additionally, estimates for self-employed workers were developed from the 1990 and 2000 census and ACS annual estimates. Employment was then distributed throughout the region based on industry sector totals by county, forecasted by Caltrans. ABAG/MTC's job estimations for 2005 and 2010 are compared to EDD data in Table 2 below. With the extensive economic impacts of the recent national recession, the Bay Area experienced a substantial decline in employment, as seen in both ABAG/MTC's and EDD's job estimations in Table 2. According to ABAG/MTC, nearly 3.5 million jobs were available in the region by the end of 2005. During the recession years however, employment growth stagnated. On average, ABAG/MTC's job estimations are 3 percent higher than EDD's.

Table 2. Employment Comparison (number of jobs)

Year	ABAG/MTC	EDD
2005	3,449,640	3,328,900
2010	3,385,000	3,291,500

ABAG/MTC's job growth forecast follows a complex process starting with determining the employment composition by industry sector, followed by distributing it to jurisdictions and PDAs. ABAG/MTC categorized their industry sectors into three major groups: knowledge-sector jobs, population-serving jobs, and all other jobs. According to ABAG/MTC, changing trends in industry and businesses will largely influence the labor force distribution, as summarized in Table 3.

Table 3. Changing Trends in Business Locations Inform ABAG/MTC's Employment Distribution Approach

Business Location Trend	Expected Changes to Employment Distribution
Knowledge based jobs, culture and entertainment activities increasing in regional centers	• More employment downtown San Francisco, downtown Oakland, and downtown San Jose expected due to growth in professional services sector • More international businesses in those downtowns expected, as well as more tourists, artists, and entertainers
Multiple activities and transit at office parks on the rise	• Many office parks are beginning to provide direct transit access, often offer housing, services, and other amenities • More businesses are providing private shuttle services for employees, support mitigating traffic congestion
Medium and small cities' downtown areas and transit corridors expanding services for downtown residents	• Demand for local transit service, housing, and transportation choices expected to increase
New vitality of industrial and agricultural lands	• Changing and diverse mix of businesses has relocated to some industrial area locations • Besides traditional industries and businesses, now food processing, high tech product development, car repair, graphic design, recycling businesses, and others moving in the area

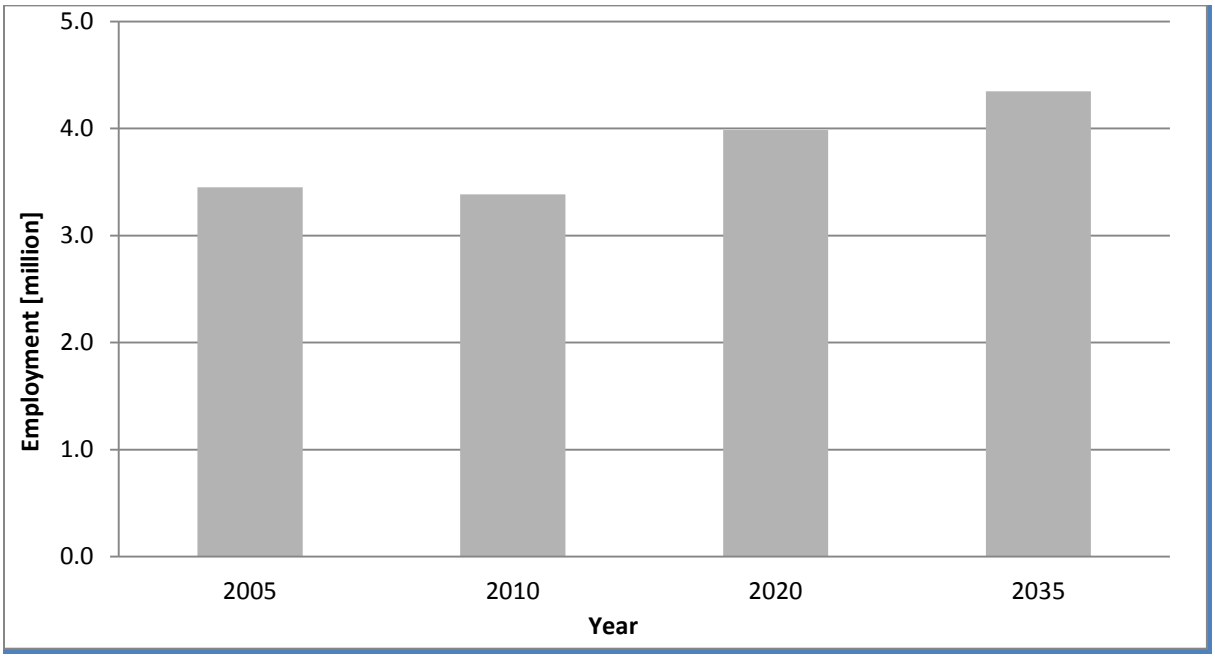
Future employment was distributed using five growth distribution factors:

- Population-serving jobs ratio
- Knowledge-sector jobs index
- Existing employment share for all other jobs
- Local planning assumptions
- Resource areas and farmland

In general, Plan Bay Area encourages job growth in the region's larger cities and PDAs with an existing employment base. PBA supports the distribution of the employment growth as planned for by the local jurisdictional plans.

As Figure 5 illustrates, ABAG/MTC expects employment to grow from approximately 3,385,000 available jobs in 2010, to 3,987,132 by 2020, and up to 4,346,762 by 2035. This change over the 25 year period represents a 28 percent increase. California's other three large MPOs expect a similar percentage job growth throughout 2035.

Figure 5. ABAG/MTC Regional Employment Projection



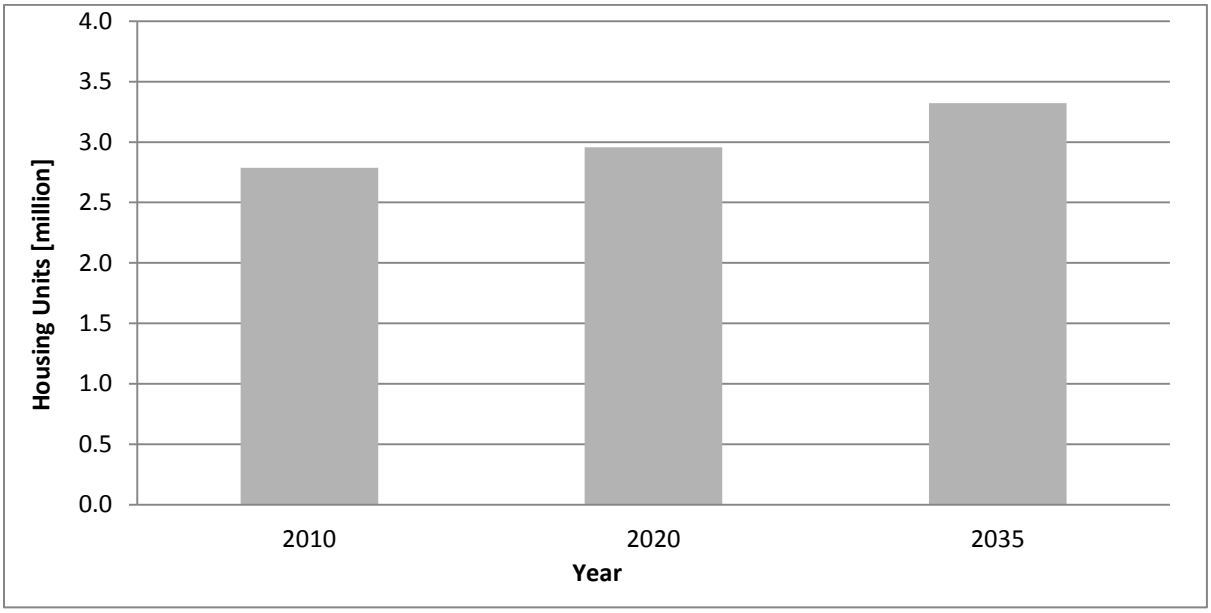
Housing

A household consists of a group of people occupying one housing unit, and can include both family and non-family members. The number of households is an important assumption in travel models because it is a primary input in determining the number of trips that occur in the region.

ABAG/MTC's 2010 household and housing unit calculations are based on 2010 census data. Although census tracts are most often used to analyze residential housing patterns, ABAG/MTC used 2010 block data, which are smaller than tracts. ABAG/MTC's housing growth forecast approach is built on the concept of sustainable development through maximizing the regional transit network, and focusing on infill and new development along the transit network and major corridors. To distribute this future growth, a locally-based assessment was performed, utilizing general plans, specific plans, and zoning ordinances, thus helping to determine the housing development potential for the target years 2020 and 2035.

ABAG/MTC estimated 2,785,948 available housing units in 2010. About 170,000 new housing units are expected by 2020 and approximately 365,000 new units between 2020 and 2035. This converts to growth rates of approximately 17,000 units per year, totaling 2,955,948 units by 2020 and approximately 24,000 units per year by 2035, totaling 3,321,190 units. The vacancy rate is expected to decline during the early forecast years, which would provide additional housing, causing a slower growth rate than in the later years. Over the 25 year period, ABAG/MTC expects housing to grow by 16 percent. This trend is shown in Figure 6.

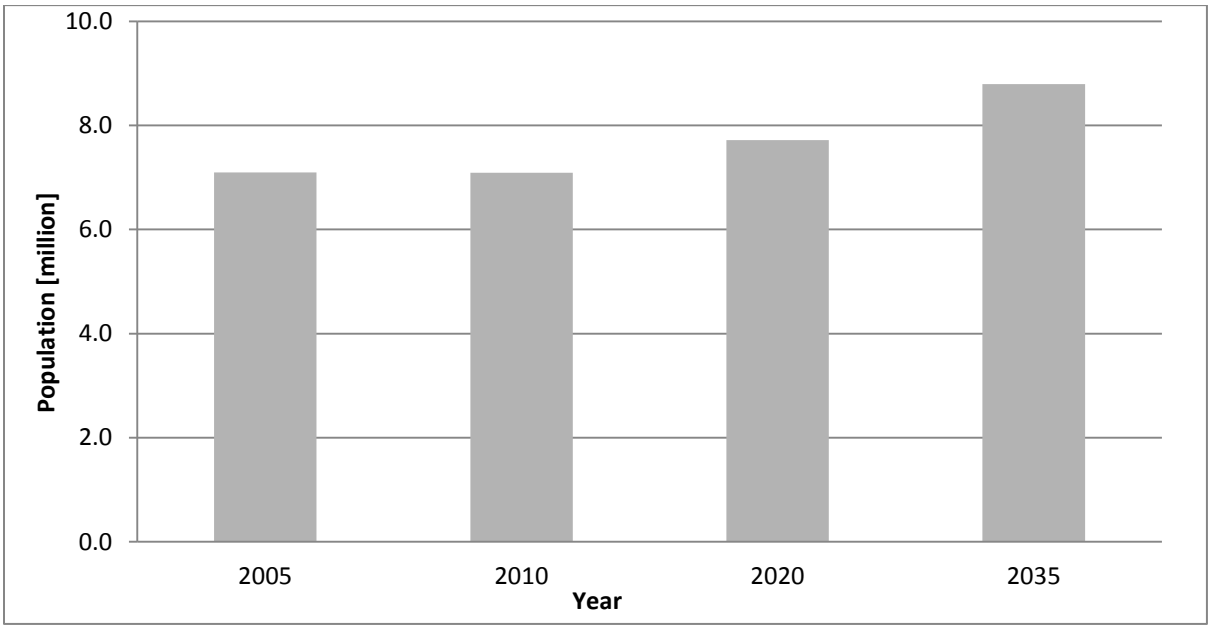
Figure 6. ABAG/MTC Region Housing Projection



Population

Population is a basic component of how present and future demand for transportation is estimated, since regional travel patterns are closely linked to population growth over time. An MPO's population assumptions have a direct effect on their estimates of regional GHG emissions. Figure 7 shows ABAG/MTC's assumed population inputs, which indicate that the region's population will grow by 24 percent between 2010 and 2035, from about 7.1 million in 2010, to 7.7 million by 2020, to just under 8.8 million by 2035.

Figure 7. ABAG/MTC Region Population Projection



ARB staff reviewed the population figures to see that they are in line with publicly-available, authoritative sources of information like those from the U.S. Census Bureau or the California Department of Finance (DOF). Existing housing law (Government Code Section 65584, et. seq.) has been integrated with RTP/SCS planning through SB 375, and requires that population growth projections developed by the council of governments be within 3 percent of those developed by DOF for the same time period. Table 4 shows a comparison between ABAG/MTC's population assumptions and the most recent population projection figures for 2020 and 2035 published by DOF.

Table 4. Population Comparison

Year	ABAG/MTC	DOF	Percent Difference
2010	7,091,000	7,150,739	1%
2020	7,718,000	7,597,338	2%
2035	8,795,000	8,250,335	6%

While ABAG/MTC's population assumptions are within three percent of DOF population projection numbers in the base year and near-term 2020 target period, the agencies' population projection for 2035 is 6 percent greater than DOF's forecast. The result is that the current plan assumes slightly more housing and travel in the region between 2021 and 2035 than would otherwise occur using the DOF forecast.

ARB staff's analysis of ABAG/MTC's population projection methodology shows that ABAG/MTC used the best available information at the time of their forecast development process. The regional agencies considered a variety of data inputs to

estimate the future population, such as the 2010 census, Bureau of Labor Statistics projections, DOF projections, local jurisdiction inputs, expert panel review, and a consultant-provided set of economic assumptions. In April 2013, ABAG/MTC held a public meeting in which a panel of representatives from ABAG, MTC, DOF, and the California Department of Housing and Community Development (HCD) explained the coordination among the agencies in developing population and housing needs forecasts. The difference in timing for each agency's forecast development process was cited as a major source of the difference between the forecast that ABAG/MTC developed and those developed by DOF and HCD. Given that population projections are continuously revisited and refined by ABAG and MTC, it is anticipated that the range of difference in projections for this time period will diminish with subsequent RTP/SCS updates.

2. Future Land Use Development

MPOs develop a long-range land use forecast as part of their transportation plan development process that estimates three major characteristics: how much development will occur in the region, where that development will be located, and at what intensity that development occurs. In this case, "development" means both households and employment, and indirectly population. In the case of ABAG/MTC, the future land use scenario takes the population, housing, and employment (the future growth forecast, discussed in the previous section) and allocates that growth to areas in the region.

This anticipated future growth pattern, or land use forecast, is a critical input to an MPO's SCS. This is because people's travel needs depend, to a large extent, on the location of homes, employment, shopping, recreation, and other destinations. Forecasting of future development patterns is an important step to developing an accurate picture of future travel demand in the region. As such, it becomes the basis from which MPOs begin planning what transportation infrastructure and services (transportation supply) are needed to serve the region's future population.

When reviewing Plan Bay Area, ARB staff's evaluation focused on the process ABAG/MTC used to generate the assumptions about future land use patterns. ARB staff also reviewed the land use forecast to verify that the projected levels of population, housing, and employment were accommodated.

Process to Develop the Land Use Forecast

ABAG/MTC used an outreach process that involved cities, counties, transportation agencies and the public. The process comprised three major steps which are discussed in more detail below:

1) Establish a set of performance metrics
2) Develop "visioning scenarios" (i.e. combinations of land use and transportation investments)

3) Evaluate each scenario against each of the metrics developed in step 1 and select a preferred scenario based on the results obtained in step 3

ABAG and MTC involved the public and stakeholders in each of the three steps summarized above. The following section expands on the steps above.

a) Establish Performance Metrics

The first step was to formulate a set of performance metrics,[1] against which alternative scenarios and the plan was to be evaluated. Performance metrics allowed ABAG/MTC to assess the various alternative strategies in a consistent way.

For performance metrics to be useful, the modeling tools employed by the MPO must be able to forecast the metric, and the metrics selected need to be at least potentially influenced by the investments and policies proposed by the MPO. ABAG/ MTC reviewed nearly 100 candidate performance metrics by examining them against a set of evaluation criteria in a collaborative process. Table 5 lists the performance metrics adopted by ABAG/MTC in January 2011.

Table 5. Performance Metrics Adopted by ABAG and MTC

Goal or Outcome	Performance Metric (by 2040, unless otherwise noted)
Required	
Climate Protection	• Reduce per-capita CO_2 emissions from cars and light-duty trucks by 15 percent in 2035.
Adequate Housing	• House 100 percent of the region's projected growth (from a 2010 baseline year) by income level (very-low, low, moderate, above-moderate) without displacing current low-income residents
Voluntary	

[1] In Plan Bay Area, MTC and ABAG refer to these as "performance targets". Here we use the term "performance metric" to avoid confusion with the term *target* used in other contexts, for example greenhouse gas reduction *targets*.

Healthy and Safe Communities	• Reduce premature deaths from fine particulates (PM2.5) by 10 percent • Reduce coarse particulate emissions (PM10) by 30 percent • Achieve greater particulate emissions reductions in highly impacted areas • Reduce by 50 percent the number of injuries and fatalities from all collisions (including bike and pedestrian) • Increase the average daily time walking or biking per person for transportation by 70 percent (for an average of 15 minutes per person per day)
Open Space and Agricultural Preservation	• Direct all non-agricultural development within the year 2010 urban footprint (existing urban development and urban growth boundaries).
Equitable Access	• Decrease by 10 percentage points (to 56 percent, from 66 percent) the share of low-income and lower-middle income residents' household income consumed by transportation and housing
Economic Vitality	• Increase gross regional product (GRP) by 110 percent — an average annual growth rate of approximately 2 percent (in current dollars).

Transportation System Effectiveness	• Increase non-auto mode share by 10 percentage points (to 26 percent of trips)
	• Decrease automobile vehicle miles traveled per capita by 10 percent
	• Maintain the transportation system in a state of good repair:
	  ○ Increase local road pavement condition index (PCI) to 75 or better of total lane-miles
	  ○ Reduce share of transit assets past their useful life to 0 percent

Source: Final Plan Bay Area, Table 4

The performance metrics in the table above enabled ABAG/MTC to evaluate plan scenarios against consistent and specific criteria. Additionally, in order to meet equity analysis requirements in federal transportation law, ABAG/MTC undertook an equity analysis. This analysis identified communities of concern in the region. Communities of concern are communities with notably high concentrations of socioeconomically disadvantaged or vulnerable populations. ABAG/MTC defined these communities and the equity priorities in these communities, in consultation

with regional stakeholders, public agency staff, and community representatives. From these priorities, the equity performance metrics, shown in Table 6, were developed. These metrics were used to evaluate the equity performance of the plan alternatives.

Table 6. Plan Bay Area Equity Performance Metrics

Equity Issue	Performance Metric
Housing and Transportation Affordability	Percent of income spent on housing and transportation by low-income households
Potential for Displacement	Percent of rent-burdened households in high growth areas
Healthy Communities	Average daily vehicle miles traveled per populated square mile within 1,000 feet of heavily used roadways
Access to Jobs	Average travel time in minutes for commute trips
Equitable Mobility	Average travel time in minutes for non-work based trips

Source: Final Plan Bay Area, Table 5.

b) Scenario Development

ABAG and MTC undertook the development of plan scenarios in two broad phases. In the first phase, ABAG/MTC developed two scenarios as visions of the Bay Area future land use and transportation system and tested those visions using the transportation network from the 2009 adopted plan. In the second phase, ABAG and MTC developed a series of alternatives that depicted a wider range of alternative land use patterns. ABAG/MTC considered general plans adopted by cities and counties, pending updates to those documents, and other local transportation and land use policies and regulations.

In the first phase, two potential land use patterns, or visioning scenarios, were developed by ABAG staff. The first, “Current Regional Plans,” reflected cities’

existing general plans and visions for growth in those plans. The second, the "Initial Vision Scenario," is a hypothetical growth pattern put forward by ABAG staff with input from local governments and county congestion management agencies. Each of these land use patterns was evaluated with the transportation network contained in the previous RTP ("Transportation 2035," adopted in 2009) and evaluated against both the performance and equity metrics described above. The results of this evaluation provided a starting point for initial conversations about where new development should occur, and how new long-term transportation investments might serve this new growth. Table 7, below depicts the relationship between these two initial land use scenarios and the Transportation 2035 network.

Table 7. Visioning Scenarios

<table>
<tr><th>Land Use Patterns</th><th>Transportation Network</th></tr>
<tr><td>Current Regional Plans.

• Generally reflects cities' current general plans for lower amounts of growth
• Growth includes 634,000 new housing units and 1.1 million new jobs.</td><td rowspan="2">Transportation 2035 Plan Network (T-2035)

• Network is the multimodal investment strategy in the existing Transportation 2035 Plan.
• Contains significant funding for operations and maintenance of the existing systems; limited expansions of highway and transit networks.</td></tr>
<tr><td>Initial Vision Scenario

• Growth pattern developed with input from local governments and county congestion management agencies.
• Land uses based on Priority Development Areas and Growth Opportunity Areas.
• Growth includes 902,000 new housing units and 1.2 million new jobs.</td></tr>
</table>

Source: Final Plan Bay Area Table 6

In the second phase, after consultation with stakeholders, ABAG/MTC staff developed a second set of scenarios which depicted a wider range of alternative land use patterns. These five land use patterns, including a revised Initial Vision scenario, were matched with one of two proposed transportation networks: either the Transportation 2035 Network (i.e., the existing long-range plan) or a Core Capacity Transit Network. The choice of network to be used with which land use scenario was made based on which network best supported the scenario's pattern of development. These land use/network combinations were then separately evaluated against the performance metrics, and then against the

five social equity metrics discussed earlier. Table 8 lists the specific land use/travel network pairings.

Table 8. Alternatives to the Visioning Scenarios Developed in Phase 2.

Land Use Patterns	Transportation Networks
Initial Vision Scenario Revised • Concentrates housing and job growth in Priority Development Areas (PDAs)	Transportation 2035 (T-2035) Plan Network • Network is the multimodal investment strategy in the existing Transportation 2035 Plan. • Contains significant funding for operations and maintenance of existing system; limited expansions of highway and transit networks
Core Concentration (Unconstrained) • Concentrates housing and job growth in locations served by frequent transit service, and/or in core Bay Area locations with a 45-minute transit commute area of the downtown areas of San Francisco, Oakland, or San Jose • Scenario is "unconstrained" due to the high levels of population and job growth that were assumed.	Core Capacity Transit Network • Significantly increased transit service frequencies along core transit network. • Keeps T-2035 investment levels for maintenance and bike/pedestrian projects; reduces T-2035 roadway expansion investments. • Requires additional capital and operating funds to pay for major expansion of transit services.
Core Concentration (Constrained) • Similar to unconstrained version above; housing and job growth is distributed to selected PDAs in the inner Bay Area, focusing on major downtowns and areas along the region's core transit network. • Scenario is "constrained" with lower levels of population and job growth than Unconstrained or Initial Vision.	
Focused Growth • Growth is distributed more evenly along transit corridors and job centers, with emphasis on development in PDAs and Growth Opportunity Areas.	
Outward Growth • Distributes greater amounts of growth to inland Bay Area, with some emphasis on focused growth near suburban transit hubs. Scenario is closer to historical trends.	T-2035 Network (See above)

Source: Final Plan Bay Area Table 7.

c) The Preferred Scenario

After evaluating the results of the second phase of scenario development and outreach to regional stakeholders, ABAG/MTC developed the Jobs-Housing Connection Strategy. This land use pattern places 78 percent of residential growth and 62 percent of job growth in PDAs throughout the region.

ABAG/MTC also developed the Preferred Transportation Investment Strategy to identify the investment approach best serving the Jobs-Housing Connection Strategy. The ABAG Executive Board and the MTC Commission adopted the Jobs-Housing Connection Strategy and the Preferred Transportation Investment Strategy in May 2012 as the preferred scenario, which was incorporated into Plan Bay Area. Table 9, below summarizes the characteristics of the preferred scenario.

Table 9. Characteristics of the ABAG\MTC Preferred Scenario

Land Use Pattern	Transportation Network
Jobs-Housing Connection Strategy • Focuses 78 Percent of new housing and 62 percent of new jobs in PDAs • Reduces GHG emissions, limits growth outside of the region's core, and preserves natural resources and open space • Reduces VMT per capita by 10 percent. • Includes sufficient housing to house all of the region's projected growth.	Preferred Transportation Investment Strategy • Devotes 87 percent of funding to operate and maintain existing transportation network. • Directs remaining funding to next-generation transit projects and other high-performing projects, to programs aimed at supporting focused growth and reducing GHG emissions, and to county-level agencies for locally designated priorities.

Source: Final Plan Bay Area Table 8.

3. Transportation Network Inputs and Assumptions

MTC's transportation network used in the trip assignment step of travel demand modeling is comprised of the regional highway network and the transit network. The highway network consists of roadway links classified by facility type. The transit network is used to model the impacts of transit and land use strategies on travel patterns throughout the region. ARB staff reviewed the coding procedures of MTC's highway and transit networks, as well as travel demand model base year link capacity and free-flow speed assumptions. The methodologies MTC used to develop the transportation network and travel demand model input assumptions are consistent with guidelines in the National Cooperative Highway Research Program (NCHRP) Report 716. The NCHRP Report 716 reflects current travel characteristics, and provides guidance on travel demand forecasting procedures and their applications for solving common transportation problems.

Highway Network

Figure 8 shows the base year regional freeway and roadway systems that are included in MTC's highway network. Each roadway link in the highway network is coded with attributes such as number of lanes, link capacity, free-flow speed, facility type, toll class type,[2] user class type, and area type. There are five highway network time periods in MTC's travel demand model: early AM (3 am to 6 am), AM peak (6 am to 10 am), midday (10 am to 3 pm), PM peak (3 pm to 7 pm), and evening (7 pm to 3 am). The regional highway network includes about 18,959 centerline miles for all freeways, arterials, and collectors, of which 4,667 lane miles are on freeways. The model's base year lane miles by type of roadway are summarized in Table 10.

MTC's development of the highway network was compared with the NCHRP Report 716 and found to be consistent with the recommended practice.

[2] Two types of tolls are coded: bridge tolls are the toll charged at the bridges; and value tolls are tolls paid to save time by shifting to use high occupancy toll lanes, known in the Bay Area as express lanes.

Figure 8. 2010 MTC Regional Highway Network

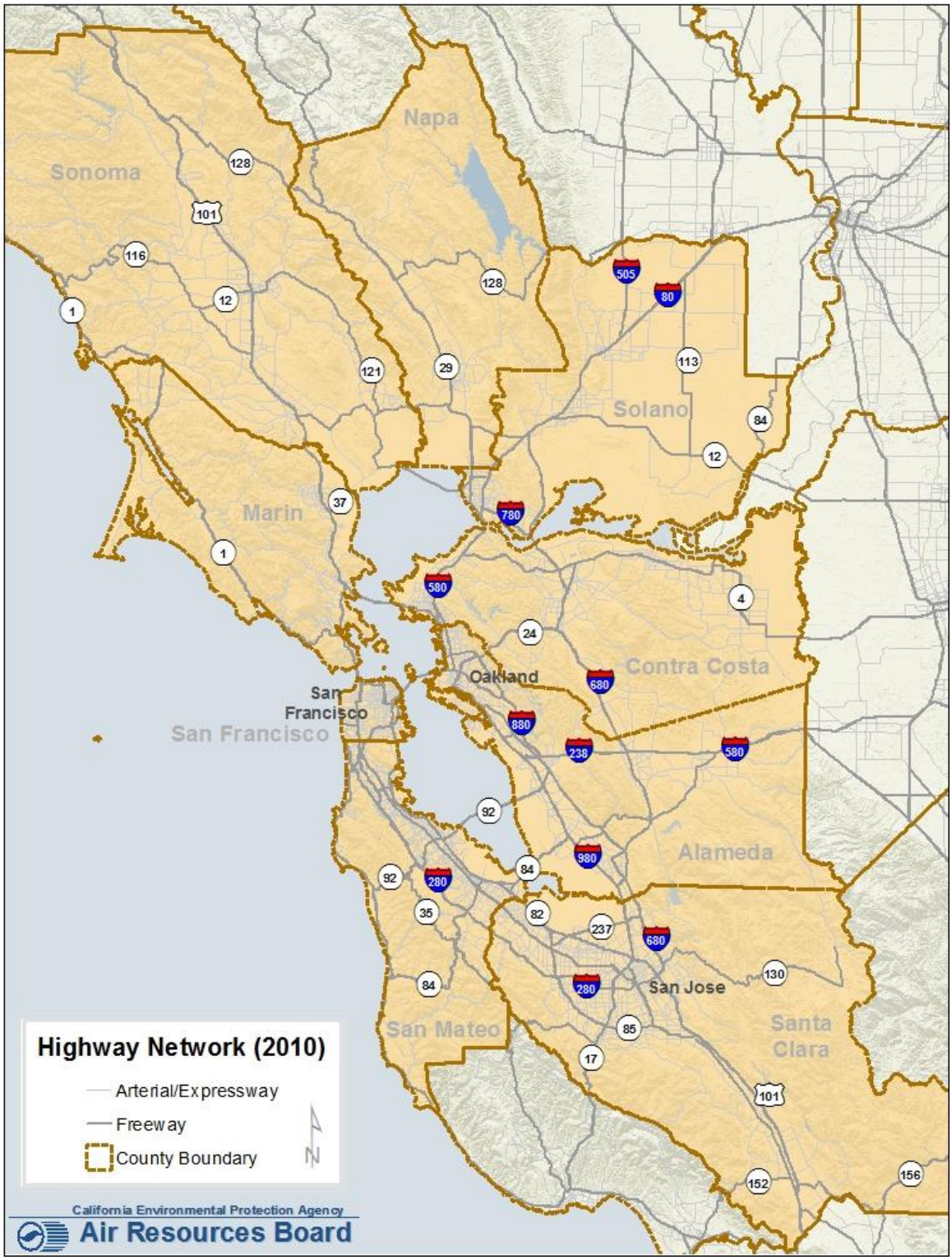


Table 10. Summary of MTC's Highway Network Inventory in 2010

Type of Roadway	Lane Miles (2010)
Freeway including managed lanes and auxiliary lanes	4,667
High occupancy vehicle (HOV) lanes	474
Express lanes	14
Mixed-flow lanes and auxiliary lanes	4,179
Arterial	8,710
Collectors	5,582

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[3] in an hour. One important reason for using link capacity as an input to the travel demand model is to measure congestion impact, which can be estimated as the additional vehicle-hours of delay traveling below free-flow speed. Table 11 summarizes MTC's free-flow speed and link capacity assumptions by facility type.

Table 11. Base Year (2010) Free-flow Speed and Link Capacity Assumptions

Facility Type	Free-flow Speed (mph)	Link Capacity (vehicles/hour/lane)
Freeway-to-freeway connector	40 to 50	1,850 to 2,000
Freeway	55 to 65	2,025 to 2,150
Expressway	40 to 55	1,450 to 1,650
Collector	10 to 35	600 to 950
Freeway ramp	30 to 40	1,450 to 1,550
Major arterial	20 to 40	900 to 1,050

The methodology used to estimate roadway free-flow speeds and link capacities in the MTC region was reviewed and found to be consistent with the practice indicated in the NCHRP Report 716.

[3] Free-flow speed is used to calculate the shortest travel time between two points in the highway network.

Transit Network

The transportation network of the MTC activity-based travel demand model also contains a transit network (Figure 9), which reflects a mix of transit operators of local and express buses, ferries, light rail, heavy rail, and commuter rail. Coded transit line attributes include, but are not limited to runtime, headways by time period, description of the route, and the direction of the route. The base year transit service coverage in the MTC region is summarized in Table 12.

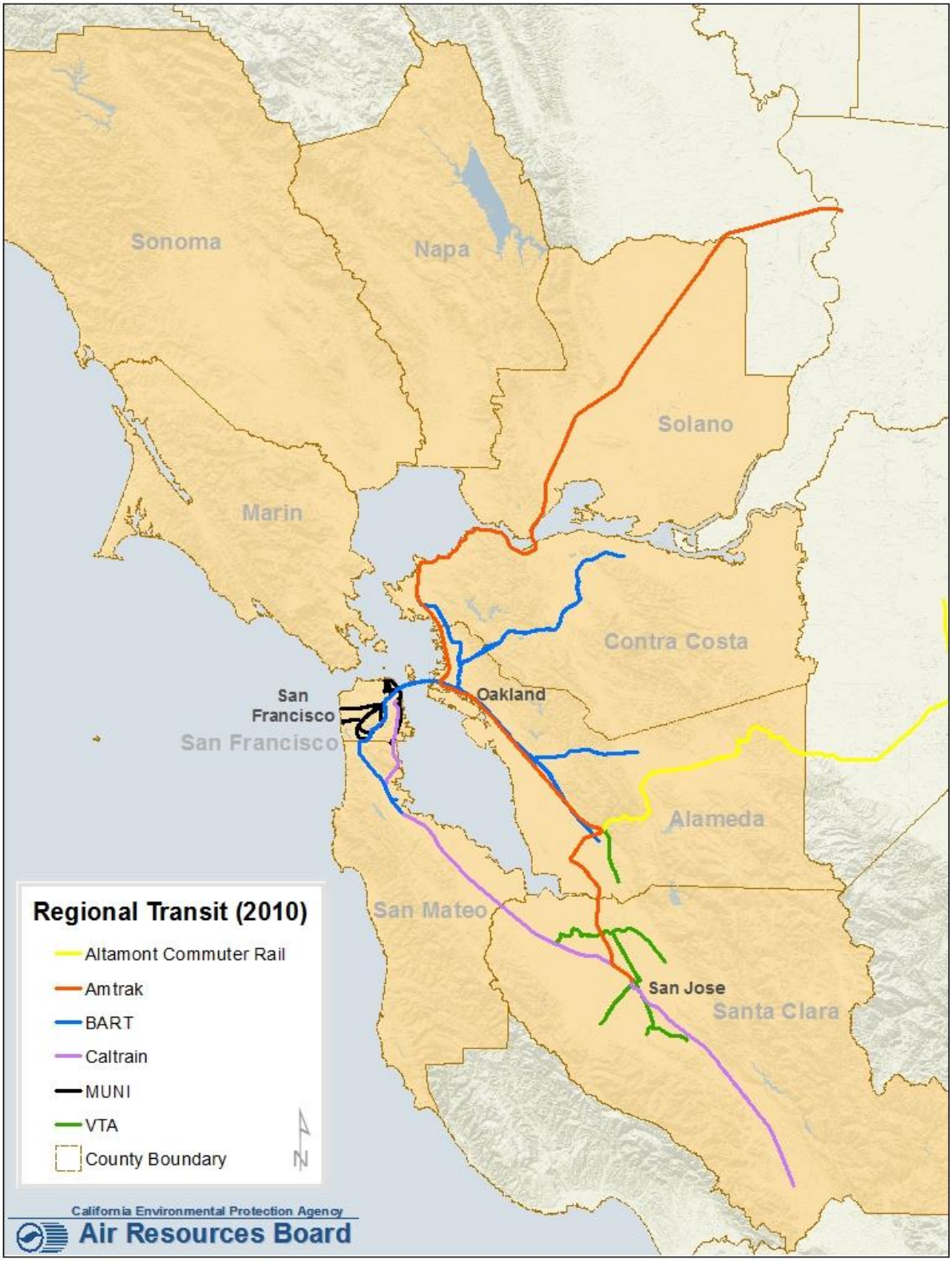
Table 12. MTC Regional Transit System in 2010

Transit System	Seat-miles[4] in 2010
Local and express bus	21,019,000
Light rail	4,057,000
Heavy rail	22,067,000
Commuter rail	7,232,000

ARB staff reviewed the transit attributes coded in the transit network and the procedures MTC followed in developing the transit network. MTC's development of the regional transit network is consistent with the procedures discussed in the NCHRP Report 716 and USDOT's "Model Validation and Reasonableness Checking Manual."

[4] A one-mile segment of a bus with forty seats is forty-seat miles.

Figure 9. 2010 MTC Regional Transit Network



4. Travel Demand Model Inputs and Assumptions

The time and length of trips based on trip destinations can influence the amount of travel within a study region. ARB staff reviewed key model inputs (e.g. number of trips produced per household by purpose) for each step of the travel model, and compared them to those from independent data sources using the methods described in the "Description of Methodology for ARB Staff Review of Greenhouse Gas Reductions from Sustainable Communities Strategies (SCS) Pursuant to SB 375." This review allowed ARB to understand the variables used in the model, the assumed values of the variables, and the sources of the model input.

Trip Generation Rates

The trip generation rate is the average number of daily person trips for a given trip purpose or mode of transportation in a planning region. Factors such as automobile ownership, income, household size, density and type of employment, and the availability of public transportation, can influence the amount of travel in a region.

MTC's model included trips on mandatory tours[5], at-work tours, and non-mandatory tours. Table 13 summarizes the daily per person average trip rates by type of tour.

[5] A tour is a unit of analysis that measures the sequence of trips, originating from a single location, such as home or work. This unit of analysis helps to better account for the influence of connections between trips on travel behavior.

Table 13. Trip Generation Rates by Type of Tours

Type of Trip	Total Daily Trips	Average Number of Trips per Person
Trips on mandatory tours[6]	10,159,000	1.4
Trips on at-work tours[7]	1,577,000	0.2
Trips on non-mandatory tours[8]	11,684,000	1.7
Total	23,420,000	3.3

Trip Distance Distribution

Trip distance, estimated using the regional highway and transit networks, was used as an input to quantify travel impedances between zones. The trip distance data by mode of transportation reported by MTC are presented in Table 14. MTC's trip distance for each mode is comparable to those reported in the 2009 National Household Travel Survey (NHTS) except for the mode of auto. The lower auto trip length in the MTC region compared to the national average is attributed to the proximity of transit and/or job centers to residential units so that residents can use transit conveniently and/or drive a shorter distance to work or other activities.

Table 14. Average Trip Distance by Mode

Mode	Average Trip Length (miles)	
	2010 MTC Model	2009 NHTS
Auto	6.9	12.09
Walk	0.9	0.98
Bike	2.4	N/A
Transit	9.1	10.18

Average Daily VMT per Bay Area Resident by County of Residence

Another input to the travel demand model is the average daily VMT reported by each county in the MTC region. Table 15 summarizes these per resident VMT or per worker VMT figures, by county. As expected, most of the trips and distance traveled are for commute purposes; the average daily VMT per worker is higher than the average daily VMT per resident for each county in the MTC region.

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[6] Mandatory tours are primary tours associated with work and school .
[7] Round-trips that are made while at work (e.g. trip to lunch from work, trip for personal errands).
[8] Non-mandatory tours are tours for purposes such as shopping and recreation.

Table 15. Average Daily VMT by County

County	Average Daily VMT per Resident	Average Daily VMT per Worker
San Francisco	7.4	12.6
San Mateo	16.7	29
Santa Clara	15.4	24.6
Alameda	15.4	25.8
Contra Costa	18.8	27.3
Solano	16.4	24.3
Napa	17.6	27.8
Sonoma	18.9	22.6
Marin	18.5	34
All Counties	15.6	23.8

Zonal Data

Zonal data inputs to the travel demand model are comprised of socioeconomic data and transportation and land use characteristics. ABAG developed the aggregated zonal demographic and employment data inputs, which include total households in each of the four income categories (i.e. $0-30K, $30-60K, $60-100K, and $100K+), population in each of the five age categories (i.e. 0-4, 5-19, 20-44, 45-64, and 65+), high school and grade school enrollment, and the number of jobs in each of six employment categories (i.e. agricultural and natural resources, manufacturing, wholesale trade and transportation, retail trade, financial and professional services, health, educational and recreational services, and other). The zonal transportation and land use characteristics are estimated parking cost, auto terminal time, and the land areas devoted to different uses. Each zone is also categorized into one of six area types (i.e. regional core, central business district, urban business, urban, suburban, and rural).

ARB staff reviewed the descriptions of the socioeconomic, transportation, and land use variables included in the zonal data inputs. Zonal data inputs of MTC's travel demand model are consistent with the practice suggested in the "Data Needed for Model" section of the NCHRP 716 report.

5. Cost Inputs and Assumptions

The costs associated with travel represent a significant factor in determining the mode of transportation used for any given trip. ARB staff reviewed the following basic travel cost components used as inputs in MTC's travel model: household time value, bridge tolls, express lane tolls, transit fares, automobile operating costs, parking costs, and

cordon tolls. MTC ran its model for 2010 using DOE's forecast, which was developed using 2009 dollars. Results are shown in Table 16.

Auto Operating Cost

Three main inputs are used in determining the perceived auto operating cost in Travel Model One: average fuel price, average fleet-wide fuel economy, and other non-fuel related operating and maintenance costs. The costs of purchasing and insuring automobiles are not included.

MTC incorporated the approach that California's MPOs adopted at the recommendation of the Regional Targets Advisory Committee to use consistent assumptions for fuel price. The future year forecasts prepared by the U.S. Department of Energy (DOE) were completed in 2010. California's MPOs developed fuel price forecasts by using a weighted average of DOE's low end estimate (weighted 25%) and DOE's high end estimate (weighted 75%) plus a 25 cent surcharge to account for the additional costs for fuel sold in California. These costs are expressed here in year 2009 dollars (consistent with the DOE forecasts). The average fleet-wide fuel economy is taken from ARB's EMFAC motor vehicle emissions model.

Table 16. Auto Operating Cost Breakdown

	2010	2020	2035	2040
Average Fuel Price/gal (in year 2009 dollars)	$3.25	$4.74	$5.24	$5.40
Miles per Gallon	21.35	24.10	30.88	31.26
Non-Fuel Related Operating Cost	$0.08	$0.09	$0.11	$0.12
Perceived Automobile Operating Cost (per mile)	$0.23	$0.28	$0.28	$0.29

Value of Travel Time

In MTC's model, the population's perceived value of time is considered in the structure of the mode choice travel model. As would be anticipated, the value of an individual's time is in direct correlation with household income. For children,

their value of time is calculated as 2/3 that of the adult. The value of time has been held constant between the baseline and future forecast years for the model.

Bridge Tolls

Bridge tolls have been held constant in MTC's model at the level in effect as of July 1, 2012. Tolls are expressed in the model in year 2010 dollars. For the San Francisco – Oakland Bay Bridge and the Golden Gate Bridge, peak-period tolls are $6, and for all other bridges the tolls are $5. Carpool tolls are generally half of the full price tolls and tolls during off-peak periods are reduced. This toll schedule is not changed for future forecast years. The only additional toll included as part of the proposed plan is a $5 toll for passenger vehicles leaving Treasure Island during the morning and evening commute periods.

Express Lane Tolls

The travel model includes the option of paying a toll for the use of an express lane (a high occupancy toll or HOT lane), thus saving time relative to the use of the adjacent toll-free mixed flow lanes. A specific price is assigned for each time of day and vehicle class for each HOT lane segment in the travel model. In real world operating conditions, prices would be optimized so as to minimize congestion and maximize utilization. Prices are held constant over the entire four hour morning and evening commute periods. Congestion is assumed to remain at the same level throughout each peak period for the travel model. The proposed prices (in year 2010 dollars) for HOT lane segments vary from 0.0 cents per mile to 18.9 cents per mile in the 2035 and 2040 scenarios. Prices differ in the 2020 scenario, but were not provided by MTC.

Cordon Tolls

MTC's plan scenario includes a $3.00 toll (in year 2010 dollars), or cordon fee, for vehicles entering the greater downtown San Francisco area during the morning and evening commute hours. This would be similar to the sort of fee charged to vehicles entering London's downtown area during peak commute hours.

Parking Cost

The price of parking is applied at the travel analysis zone (TAZ) level in the model. The price is expressed in hourly rates for both long term (daily) or short term (hourly) parking. For both long and short term parking, the rates for all lots in a TAZ are averaged. For long term parking, the average monthly rate is divided by 22 days per month and 8 hours per day to generate an hourly parking cost. For short term parking, the average hourly rate is used (and is typically higher than the hourly rate for daily parking). The areas where paid parking can generally be found are greater downtown San Francisco, downtown Oakland,

Berkeley, downtown San Jose, and Palo Alto. For future forecast years, it is assumed that the cost of parking will increase following a linear trend.

Transit Fares

For the model, transit fares are assumed to remain constant starting from the 2010 baseline through all future forecast years. However, it is also assumed that travelers pay the full cash fare for each transit service. For example, the full base fare for the San Francisco Municipal Transit Agency (MUNI) in year 2010 dollars is $2.00, the base fare for Alameda/Contra Costa County (AC) Transit is $2.00, and the base fare for Golden Gate Transit's Marin County to San Francisco bus service is $3.65. MTC uses this as a simplified approach consistently throughout all years of the RTP/SCS.

C. Modeling Tools

ABAG/MTC used several models to quantify GHG emissions resulting from implementation of Plan Bay Area (Figure 10). ABAG/MTC uses a land use model and an activity-based travel demand model to calculate changes in land use patterns and travel demand, based on a number of different modeling inputs, such as population, employment, and potential infrastructure investment. Based on these and other inputs, the land use model predicts the location of housing, jobs, and other activities for future years, and the travel demand model produces vehicle activity outputs such as VMT, vehicle hours traveled, number of vehicle trips, and average speed.

MTC estimates GHG emissions reductions from its plan for 2020 and 2035, using the VMT outputs from its travel demand model. VMT outputs are converted to GHG emissions by running ARB's vehicle emissions model, EMFAC 2011. MTC also makes use of off-model calculations to account for GHG emissions reductions from its climate initiative programs. The section below describes the various models ABAG/MTC used to develop and analyze Plan Bay Area, as well as planned model improvements for the next RTP/SCS update.

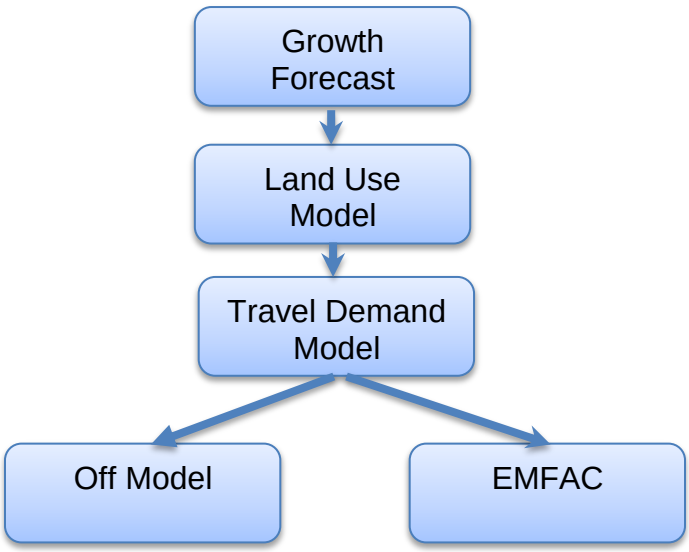


Figure 10. ABAG/MTC's Modeling Tools

1. Land Use Model

The land use model Urban Simulation (UrbanSim) is the first of three modeling tools that ABAG/MTC uses to forecast land use changes in the nine county region. This tool was developed for ABAG by the University of California, Berkeley, to understand the interactions between the transport system and land use changes. MTC incorporated ABAG's updated control total estimates of regional population, households, and employment, as well as planning policies into UrbanSim to forecast land use change in the region.

Input data in UrbanSim are from the U.S. Census Bureau's 2010 Public Use Microdata Sample (PUMS), Employment Development Department (EDD), and local employment and economic surveys. The total number of employees by sector, demographic projections, and the total number of households by income category within the region for base and forecasted years were prepared by ABAG and input into UrbanSim. UrbanSim uses these inputs to simulate the real-world location/employment/development choices and actions of households, businesses and developers through sub-models. Sub-models include economic and demographic transition models, employment and household relocation models, employment and household location choice models, a real estate development model, and a land price model.

The outputs of UrbanSim are: households by income, age, size, and presence of children; employment by industry and land use type; acreage of dwelling units by type; square feet of nonresidential space by type; and real estate prices. UrbanSim is integrated with the MTC travel demand model to improve the interaction between transport system changes and land use changes. Projected land use patterns and spatial distribution of activities from UrbanSim are input to MTC's regional travel demand model at an aggregated transportation analysis zone (TAZ) level for base and forecasted years.

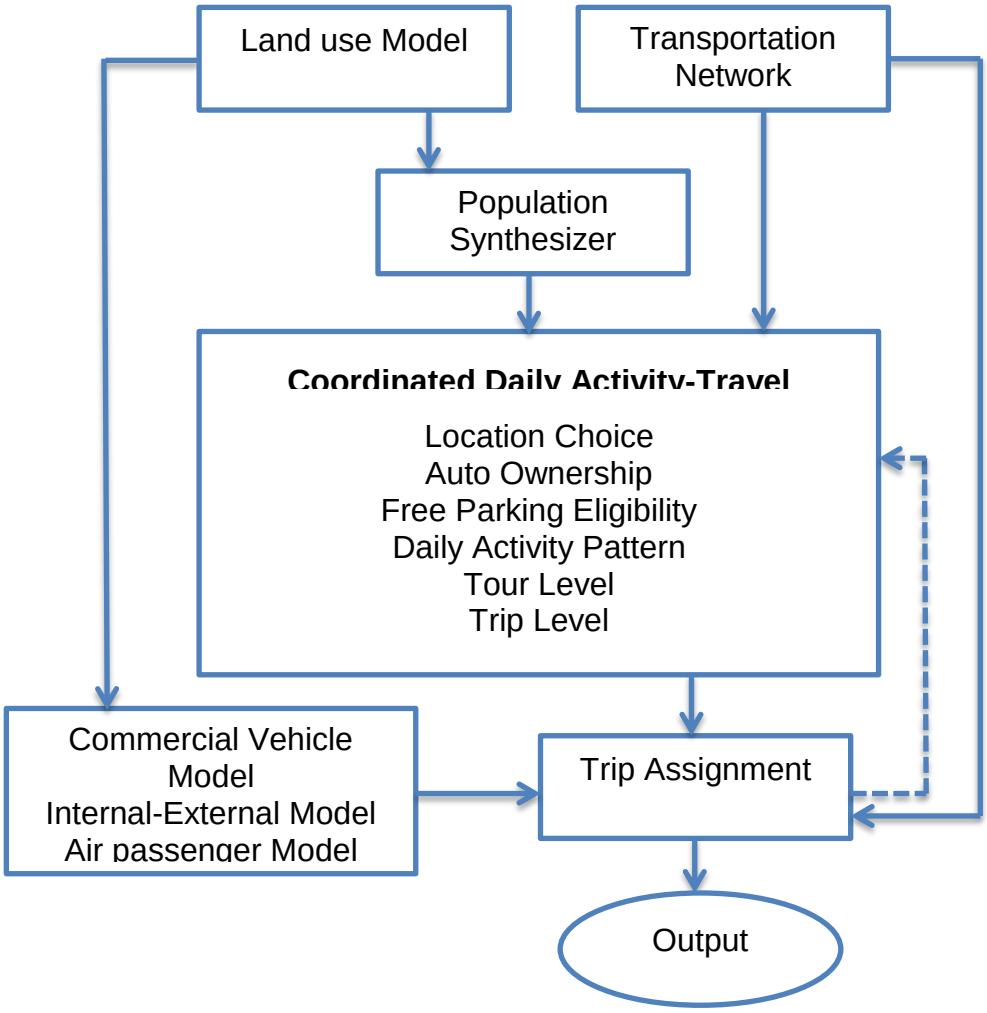
2. Activity-Based Travel Demand Model

The travel demand model MTC used for Plan Bay Area is based on the Coordinated Travel Regional Activity-Based Modeling Platform (CT-RAMP) called Travel Model One. Travel Model One simulates activities of individual person travel choices including intra-household interactions between household members, and households in the region. MTC used Travel Model One to assess the long-term needs of the nine-county San Francisco Bay Area region's transportation system such as roadways, transit planning, and goods movement, as well as to perform federally required air quality conformity and GHG analyses under SB 375.

Key components of the Travel Model One are transferred from San Francisco County Transportation Authority, the Atlanta Regional Commission, and Mid-Ohio Regional Planning Commission models. The nine-county San Francisco Bay Area is divided into 1,454 zones to allocate socioeconomic and land use characteristics. Travel Model One

explicitly models intra-household and joint travel that is critical for realistic modeling of the individual decisions made in the households. Similar to other travel demand model types, it is an aggregation of a number of different sub-models (Figure 11). This section reviews the key components of Travel Model One: population synthesis, location choices, auto ownership, free parking eligibility at work location, daily activity pattern, tours/trips by time of day and mode of travel, and trip assignment. This section also discusses the model validation process MTC performed to establish the credibility of the model's outputs.

Figure 11. MTC's Travel Model One



Population Synthesizer

The population synthesizer is the first step of Travel Model One. It uses household information from the U.S. census and zone levels to estimate a synthetic population[9] for the entire Bay area for the base and forecast years. The synthetic population creates a list of households, with various attributes for each synthesized person, so it is well suited to determine travel behavior. Attributes include the household to which the person belongs, type of person (full-time worker, part-time worker, retired, schoolchild, or university student), and whether it is a high-, medium-, or low-income household. To develop the base year synthetic population, the model first estimates the number of households in each zone with detailed socio-demographic census data. Public Use Micro-data Samples (PUMS)[10] are then matched to zonal level information using control variables such as household size, presence of children in household, number of workers in household, income, age, and number of housing units in household structure. An iterative proportional fitting procedure is used to match the control totals and its distributions.

The population synthesizer creates a synthetic population for the base year and for each forecast year. The key difference between the base and future years is the initial distribution. The control variables for the future year are based on the land use forecasts developed in UrbanSim. Other procedures were followed, similar to base year, to estimate the synthetic population. To validate the population synthesizer, MTC used the year 2000 census data.

The variables MTC used to develop the control totals and the population distributions in the base and future years are reasonable when compared with the 2000 census data. Table 17 shows the percent difference between the synthesized population and the census population. At the zonal level, comparisons among all variables matched within less than two percent difference. ARB staff recommends in the future that MTC also validate the population synthesizer by back-casting to 1990 and compare the results to the observed data to increase the confidence on the estimates. In addition, model documentation should provide key statistics such as the correlation coefficient between the model and census data, average household size by county and average number of workers per household by county. This would help in the understanding of the level of details at which the population synthesizer can reasonably estimate key attributes used in the travel forecasting model.

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[9] The synthetic population represents a close-to-reality human population for use in Travel Model One.

[10] A sample of population and housing unit records from the American Community Survey.

Table 17. Comparison of Travel Model One and 2000 Census Population

Variables	Population Synthesizer	Census (2000)	Percent difference (%)
Total persons	6,672,830	6,764,730	1.4%
Total households	2,466,190	2,466,200	0.0%
Total employed residents	3,389,000	3,394,820	0.2%
Single-family dwelling units (%)	63.1	63.1	0.0%
Multi-family dwelling units (%)	36.9	36.9	0.0%
Households with zero workers (%)	20.1	20.1	0.0%
Households with income $100K+ (%)	27.8	27.8	0.0%

Coordinated Daily Activity-Travel Pattern

Travel Model One simulates the full day activity and travel schedule of each person in the Bay Area in two stages: long term and short term. The long term decision model predicts primary work/school location, auto availability for each household, and availability of free parking for workers, since the choices do not change for months or sometimes for years. Long term decisions are then fed into the short term decision model to capture the complex aspects of travel decisions such as mode, time of travel, frequency, and other individual decision-making processes of travel choices. The daily activity-travel pattern model captures the behavioral aspects and travel decisions at each level. Travel Model One is implemented by replacing and extending a certain portion of a typical four-step model (e.g., trip generation, trip distribution, and mode choice) into several distinct sub-models including a location choice model, an auto ownership model, a free parking eligibility model, a daily activity pattern model, and a tour and trip level model. This section describes and evaluates each sub-model in detail.

- Location Choice Model

  The location choice model predicts the primary destination location for each worker, school-aged child, and college student in the nine-county region. It uses a multinomial logit model[11] structure with constraints on residence location, household, and person characteristics. The model uses employment by categories (retail, agriculture, manufacturing, trade, health service, and other), and enrollment in school and colleges to predict the primary destination location. The location choice model also uses accessibility variables such as level-of-service and trip length to reflect the ease of travel between zones. Some of the parameters for this model were borrowed from the San Francisco County

[11] A special form of regression used to analyze the relationship between predictor variables and a categorical outcome variable.

Transportation Authority (SFCTA) Model. MTC calibrated the model for the year 2000 using the Census for Transportation Planning Package (CTPP) and the Bay Area Travel Survey (BATS 2000).

ARB staff reviewed the variables used in the location choice model and overall, the location choice model predicted destination within the expected range. The location choice model uses household income by employment category, accessibility to various modes, and area type to capture land use characteristics. Area type and location variables played a significant role in explaining location choices in the region. The ease of travel between zones, which is captured using the mode choice logsum variable, influences the location choice.

ARB staff also evaluated average distance between home and work, home and school/college, and county-to-county work/school trips. Table 18 shows a comparison of the average distance between home-to-work and home-to-school/college predicted by the location choice model and the observed data. The distance distributions for school and college trips matched very closely with less than 5 percent difference, whereas the difference between the model and observed data for distance to work was 6.3 percent. MTC attributes this difference to higher-income workers traveling further distances to work than lower-income workers. The comparison of county-to-county worker/student flows from the model and CTPP seems reasonable.

Table 18. Average Distance Between Home and Work/School/College

	Model (miles)	Observed data (miles)	Difference (%)
Average distance to work (one-way)	12.7	11.9	6.3%
Average distance to school, (one-way)	3.7	3.7	0.0%
Average distance to college, (one-way)	7.4	7.1	4.1%

To allow for evaluation of the model's structure and overall performance of the location choice model, ARB staff recommends that MTC provide goodness-of-fit statistics in the model documentation. It is insufficient to check only the average trip lengths for this portion of the evaluation. The frequency distribution of trip lengths should also be checked using coincidence ratios, which were not readily available.

- Auto Ownership Model

The auto ownership model is applied at the household level and reflects five ownership choices: zero car, one car, two cars, three cars, and four or more cars. It utilizes a multinomial logit model structure with variables such as number of workers, household income, age of household members (to indicate driver's license eligibility), residential and employment density, land use mix, parking cost, travel time from residence to work for each worker, and auto and transit accessibility. MTC developed the model using BATS 2000 data and calibrated the model at the county level using year 2000 census data.

ARB staff reviewed the structure and variables used in the auto ownership model. The auto ownership model showed a good fit with a rho-squared[12] value of 0.456. There is a strong relationship between the number of people aged 18-24 in a household and owning at least one auto, in MTC's auto ownership model. The number of vehicles available per household decreased when the density increased. The model followed the recommendations in CTC's 2010 California Regional Transportation Plan Guidelines (RTP Guidelines) that travel demand models should have an auto ownership model, and be sensitive to land use and transit accessibility.

Auto ownership at the county level from Travel Model One was compared with household data. In San Francisco and Alameda County, MTC's model originally showed a systematic deviation from the observed data in the zero vehicle households. To address this issue MTC included a geographic constant to better match the observed distribution. After incorporating the geographic constant this has improved the match between the observed and modeled data, as shown in Table 19. To better estimate the GHG reductions associated with SCS strategies in the future, ARB recommends that the auto ownership model be validated against the Department of Motor Vehicle data.

[12] This indicates how good the model fits the data points. In other words, it indicates the goodness-of-fit of the model.

Table 19. Auto-Ownership Distribution

County	Zero Vehicle HH		One Vehicle HH		Two Vehicle HH		Three plus Vehicle HH	
	Observed (%)	Model (%)	Observed (%)	Model (%)	Observed (%)	Model (%)	Observed (%)	Model (%)
San Francisco	28.4	29.2	42.0	42.0	22.3	21.8	7.4	7.0
San Mateo	6.0	5.5	31.8	32.3	39.9	40.9	22.2	21.3
Santa Clara	5.6	6.3	28.9	28.6	41.0	40.8	24.5	24.4
Alameda	10.8	10.7	34.8	31.7	36.2	37.5	18.2	20.1
Contra Costa	6.5	4.3	30.3	31.9	41.1	43.3	22.2	20.5
Solano	6.6	6.7	28.9	30.9	40.0	39.9	24.5	22.5
Napa	6.2	6.2	32.2	32.8	39.9	40.1	21.7	20.9
Sonoma	5.7	5.7	31.5	30.7	40.2	41.2	22.6	22.3
Marin	5.0	5.6	34.8	36.5	42.3	42.1	18.0	15.7

- Free Parking Model

The free parking model is used by MTC to reflect the cost of driving to work when individuals consider mode choice. It predicts the availability of free parking at work locations where parking charges are otherwise applicable (e.g., San Francisco, Berkeley, Oakland). This model is based on a model from the Mid-Ohio Regional Planning Commission. It utilizes a binary logit model structure with variables such as total employment, household size, income, work location, and number of cars per household. MTC calibrated the model at the county level using the zonal data from ABAG and BATS 2000.

To evaluate the free parking model, ARB staff reviewed the variables used in the model. The predictive capabilities of the free parking model are reasonable. The high income group and household size variables were statistically significant as expected. This model included three sets of geographic constants to capture the geographic distribution of free parking at the workplace. The free parking availability predicted by Travel Model One was compared with the observed data (BATS 2000), as shown in Table 20. The free parking availability matched closely with less than 5 percent difference with observed data.

Table 20. Employees with Free Parking by County

County	Model (%)	Observed (%)	Difference (%)
San Francisco	6.0	5.9	-0.1
Santa Clara	54.4	57.4	3.0
Alameda	45.7	47.7	2.0

- Daily Activity Pattern Model

The daily activity pattern (DAP) model is similar to the trip generation step in a four-step model. The model provides detailed daily travel activity for each person in the synthetic population. This model was transferred from the Atlanta Regional Commission's travel demand model. It uses a multinomial logit model structure and estimates travel activities at a temporal resolution of one hour. The DAP model includes three activity patterns: mandatory (predicts the number of home based work, school, or college activities, and extra stops a person might make for other activities); non-mandatory (personal business, shopping, and social/recreational activities); and home (only in-home activities). This model also predicts the number of tours, frequency, time of departure and arrival, and duration of each tour. An important feature of the DAP model is its linkage across household members. In other words, this model allows two or more people to travel jointly for any travel activity. For example, the model may predict when individuals could carpool for shopping or eating out. After joint tours are determined, the remaining time left for additional activities are updated for each person in the synthetic population.

The DAP model utilizes variables such as person (age, gender, employment status, school/college student), household (auto ownership, income), zonal characteristics (accessibility, density), and level of service by time of day. The DAP was calibrated by MTC using BATS 2000 at the person tour level.

Overall, the modeled tours by person types closely follow the observed data. Auto ownership, demographics, and accessibility variables strongly influence the number and the duration of tours. The signs and coefficients of each variable in the DAP model seem reasonable. Table 21 provides a comparison of modeled and observed shares of tours per day by person type. Both mandatory and non-mandatory modeled tours are within 5 percent of their corresponding observed tours, whereas in-home activities by person type are underestimated by 2 to 19 percent. In the future, ARB staff recommends that MTC devote more resources to model validation of this step, since it is a key component of Travel Model One to predict the travel activities in the region.

Table 21. Tours by Person Type per Day

Person Type	Mandatory		Non-mandatory		Home	
	Observed (%)	Modeled (%)	Observed (%)	Modeled (%)	Observed (%)	Modeled (%)
Full-time worker	81.3	81.6	10.1	10.3	8.6	8.1
Part-time worker	60.1	60.4	27.5	27.8	12.3	11.8
Non-worker	--	--	81.2	81.2	18.8	18.8
Retired	--	--	78.2	78.1	21.8	21.9
University student	70.0	70.2	22.0	22.1	8.0	7.7
Student driving age	76.3	76.6	10.8	10.7	12.9	12.7
Student of non-driving age	74.7	75.4	13.8	14.2	11.5	10.4
Pre-school child	40.6	41.1	36.3	37.0	23.1	21.9

The average tour length for non-mandatory tours was also evaluated. Table 22 shows a comparison of the average distance predicted by the DAP model and the observed data. Average tour length for non-mandatory tours varies between 2 percent and 18 percent, which MTC attributes to poor observed data. In the BATS 2000 survey, the primary destination of a tour was not asked; rather, it was inferred from the pattern of stops. To better evaluate the model structure and overall performance of the DAP model, ARB staff recommends that in the future, goodness-of-fit statistics be provided in the model documentation.

Table 22. Average Tour Length for Non-Mandatory Tours

Average distance	Modeled data (miles)	Observed data (miles)	Difference (%)
Shopping	4.3	4.5	4.4%
Eat out	5.7	6.3	9.5%
Visit	5.3	5.9	10.2%
Maintenance	5.6	5.9	5.1%
Discretionary	5.4	5.9	8.5%
Escort	4.0	3.9	-2.6%
At-work	3.1	3.8	18.4%

- Tour-Level Model

A tour-level model is used to predict the primary mode choice for all tours predicted in the DAP model. It uses a nested logit model structure to forecast the main tour mode, from the tour origin to the primary destination, and back to the origin. Once the daily activity pattern has been estimated for each person, the model schedules the tours that he or she would be expected to take. The tour-level mode choices include drive alone, shared ride (2 persons and 3 or more persons), drive-to-transit, walk-to-transit, bike and walk. The model further splits the auto mode into free or pay, and transit into specific modes (BART, express bus, commuter rail, Light Rail Transit). The model also allows travelers to use walking as a mode for any trip in a tour, and allows travelers to switch between transit and auto modes. This model was transferred from SFCTA and estimated using BATS 1990 data such as zonal characteristics of origin and destination zones, in-vehicle travel time, other travel time, cost, level of service, household auto ownership, number of stops in a tour, initial wait time, and transfer wait time.

Table 23 shows a comparison of modeled and observed mode share for all trip purposes in the year 2000. Overall, the tour-level model results track closely, and are consistent with, the observed data.

Table 23. Comparison of Mode Share for All Trip Purposes in 2000

Mode	Observed data (percent of total)				Model Results (percent of total)			
	Work	School	College	Shop	Work	School	College	Shop
Walk	2.6%	13.4%	7.6%	8.8%	2.6%	13.9%	8.2%	8.0%
Bike	1.6%	1.5%	1.2%	1.2%	1.7%	1.5%	1.3%	1.1%
Drive alone	56.6%	3.6%	33.7%	55.3%	56.3%	3.5%	33.1%	59.6%
Shared ride 2	15.7%	22.1%	16.1%	17.5%	15.7%	21.8%	16.0%	16.9%
Shared ride 3+	9.4%	49.9%	15.7%	13.3%	9.4%	49.6%	14.8%	11.3%
Walk-transit	9.6%	9.2%	22.1%	3.6%	9.9%	9.4%	22.0%	3.0%
Drive-transit	4.4%	0.3%	3.7%	0.2%	4.4%	0.3%	4.6%	0.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

In the estimated nested logit model, the coefficients of key variables used in the model are correctly signed. The coefficient on the walk mode is generally significantly higher than the coefficient on the bike mode, indicating the relative inconvenience associated with the walk mode. This is well captured in this model due to the inclusion of zonal topographic characteristics. The autos per worker constant in the model (autos=0, autos<workers, autos>=workers) was significant. This indicates that there is a higher probability to choose a walk/bike mode in cases where the number of autos is zero or less than the number of workers in households. Various demographic and socioeconomic attributes of both households and individuals play significant roles in the model.

MTC's mode choice model was calibrated and validated using the BATS 1990 data. In the future, to better estimate the GHG reductions associated with SCS strategies, MTC should revisit and recalibrate the mode choice model using the latest household travel survey data. Model documentation should include the model estimation process, estimated parameters, and statistical significance of the estimates.

- Trip-Level Model

In the trip-level model, estimated tours are converted into trips. The trip-level model is applied after all tour-level models and is constrained by tour-level predictions. For example, if a person bikes to work he/she cannot drive a car back home from work. Intermediate stop locations within a tour are predicted based on the constraints of tour origin and the primary destination, as well as trip characteristics such as tour purpose, tour mode, stop purpose, person type, and household characteristics. The trip-level model also predicts the mode for each trip on a given tour. The variables used in the trip-level mode choice component are similar to those in the tour-level mode choice model.

The model structure of both trip-level stop location and mode choice sub-models are consistent with that of the tour-level models, respectively. It is observed that the stop distance on a tour makes a significant contribution in determining the location of each trip on a tour. In the trip-level mode choice model, the coefficients of in-vehicle time and other travel times have correct signs and values are within the reasonable ranges as indicated in the FHWA guidelines. They are generally greater in absolute value than those estimated in the tour mode choice models, indicating higher elasticities with respect to time and cost for each trip mode given the tour mode. The model constants were adjusted to match the tour mode distribution. ARB staff recommends that in the future, the model documentation elaborate on how the model constants were adjusted and which parameters were estimated.

Trip Assignment

The final step in Travel Model One is trip assignment. This step consists of separate highway and transit assignments. The trip assignment step of Travel Model One is performed by converting person-tours to vehicle trips by mode and time period, aggregating those trips with internal-external, commercial, and air passenger trips, and assigning them to the highway and transit networks. Travel Model One runs over five time periods using multi-class user equilibrium assignments to assign vehicle trips on the transportation network for drive alone, shared rides, and all other vehicles. When all trips are assigned to a network, it estimates the total number of trips by mode, and the volume of vehicle traffic in each link. It also predicts the congested travel time in the entire transportation system by considering roadway capacity. MTC estimates effective roadway capacity of each facility by considering facility type and area type. This allows for consideration of priority lanes for shared rides and no-truck routes. Transit assignment is predicted by accounting for the congested travel time from the highway assignment. The times taken to access, egress, and transfer from one transit vehicle to another are weighted twice that of the travel time in the general purpose lane. For the assignment process, MTC used convergence criteria of 0.0005 and estimated the congested speed and volume/capacity ratio for the entire travel network.

Travel Model One uses a capacity constrained assignment function to estimate link volumes and speeds. The root-mean squared error (RMSE)[13] for daily traffic assignment in Travel Model One is 0.30 or 30 percent. MTC's practice in trip assignment is consistent with CTC's *2010 California RTP Guidelines* (RTP Guidelines). Further, Travel Model One has a correlation coefficient of 0.922 between the modeled and the observed volumes, indicating that the model closely follows observed data. Table 24 compares average weekday traffic volumes to observed traffic counts. Overall, Travel Model One underestimated traffic volumes by about 7.2 percent in 2005. MTC attributes this largely due to poor observed data because the Caltrans highway count database has few observed data for these facilities.

[13] RMSE measures average error between observed and modeled traffic volumes on links.

Table 24. Comparison of Estimated and Observed Traffic Counts in 2005

Facility type	Modeled	Observed	Difference (%)	FHWA Guidelines (%)
Freeway	11,157,023	11,921,536	-6.4%	±7
Major Arterials	939,317	1,091,728	-14.0%	±10
Collector and local	33,273	60,213	-44.7%	±20

Table 25 compares the modeled daily transit boardings by mode to the observed data from transit agencies. Generally, the transit boarding predicted by Travel Model One in the year 2005 is within 12 percent difference of the observed data. However, commuter rail ridership in the region is underestimated by 51 percent compared to the observed boarding data. MTC attributes this to artificial competition in the model between the commuter rail and new express bus service, and the extension of BART to the San Francisco airport.

Table 25. Comparison of Estimated and Observed Transit Boardings in 2005

Transit Mode	Modeled	Observed	Difference (%)
Commuter Rail	17,330	35,250	-50.8%
Heavy Rail	341,159	335,860	1.6%
Express	47,593	44,665	6.6%
Ferry	12,836	11,498	11.6%
Light Rail	177,954	168,434	5.7%
Local	1,007,374	933,628	7.9%

Model Validation and Peer Review

Model validation is a critical step in the development of any regional travel demand model. It establishes the credibility of the model to predict future travel behavior. The following analysis references the recommendations and requirements in the RTP Guidelines which MTC followed to enhance the modeling capabilities and validation procedures (see also Appendix A).

In performing model validation, MTC conducted both a base year validation of Travel Model One as well as future year validation, as recommended by the CTC Guidelines. Base year validation is also called static validation and is performed by comparing model results to observed data. For static validation, MTC compared model outputs to observed data as a check on the reasonableness of its modeling results. Future year (or dynamic) validation tests the predictive capabilities of the model by changing the input data for future year forecasts.

As part of the peer review process, MTC hired a consultant to review the model codes and to recommend improvements. Releasing the peer review document would help other MPOs to learn from MTC's experience and incorporate changes into their travel demand models. Further, this would add value to the existing literature on activity-based travel demand models. The RTP Guidelines also recommend that peer reviews be made publicly available as a part of the model documentation.

Current model documentation of Travel Model One needs significant improvements. As indicated in the RTP Guidelines, an MPO should include a goodness-of-fit measure derived from sub-model specification, and should include a comprehensive list of output metrics. To improve the transparency of the Travel Model One, MTC staff should work closely with all stakeholders to define the model needs and applications at the beginning of the process. MTC staff should coordinate with various stakeholders on modeling issues, and work to build consensus on socioeconomic and demographic forecasts. Model documentation should thoroughly describe the procedures used in model development, calibration, and validation. Model documentation is essential for model users and important for informing stakeholders on model processes.

Planned Model Improvements

This section describes the planned modeling improvements at MTC for the next RTP. In order to accurately model detailed travel movements throughout the region, MTC is planning to enhance the TAZ structure. MTC is also planning to improve the sensitivity to active transportation by enhancing the bike and pedestrian network in the model.

MTC is also in the process of developing an enhanced land use model under the UrbanSim model framework. This model is intended to predict economic activity associated with land use as a result of changes in transportation investments and policies. MTC plans to integrate the UrbanSim model with Travel Model One in order to better evaluate the effects of transportation and land use policy changes through interactions between variables and a feedback mechanism.

3. EMFAC Model

ARB's Emission Factor model (EMFAC2011) is a California-specific computer model which calculates weekday emissions of air pollutants from all on-road motor vehicles including passenger cars, trucks, and buses for calendar years 1990 to 2035.
The model estimates exhaust and evaporative hydrocarbons, carbon monoxide, oxides of nitrogen, particulate matter, oxides of sulfur, methane, and CO_2 emissions. It uses vehicle activity provided by regional transportation planning agencies, and emission rates developed from testing of in-use vehicles. The model estimates emissions at the statewide, county, air district, and air basin levels.

The EMFAC2011 modeling package contains three components: EMFAC2011-LDV for light-duty vehicles, EMFAC2011-HD for heavy-duty vehicles, and EMFAC2011-SG for future growth scenarios. EMFAC2011-SG uses the inventory from EMFAC2011-LDV and EMFAC2011-HD modules and scales the emissions based on changes in total VMT, VMT distribution by vehicle class, and speed distribution. To estimate per capita CO_2 emissions, MTC estimated passenger vehicle VMT and speed profiles for the region and applied them to the EMFAC2011-SG model. MTC then divided the estimated CO_2 emissions for passenger vehicles by the year 2005, 2020, and 2035 residential populations to obtain CO_2 emissions per capita.

4. Off-Model Adjustments

MTC used off-model estimates to account for GHG emissions reductions from the plan's climate initiative strategies. Off-model estimates were provided for the following strategies: regional electric vehicle (EV) chargers, vehicle buy-back and plug-in electric vehicle (PEV) purchase incentive, clean vehicle feebates, car sharing, smart driving, a commuter benefit ordinance, and vanpools.

The innovative concepts put forth in these strategies, such as increasing the proportion of clean vehicle miles driven in the region, and encouraging the use of car sharing and alternative modes for commuting are sound, and likely to support reduction in regional GHG emissions. The region's proposed regional EV chargers, vehicle buyback/PEV purchase incentive, and feebate programs will support the goals of California's Advanced Clean Car regulation. Local policies like these are essential for increasing awareness, and play an important role in maintaining consumer demand for advanced vehicle technologies as they are introduced into the market.

MTC developed strategy-specific quantification methods and assumptions for estimating program GHG emissions reductions. The methodologies consider a reasonable range of factors. In many cases, however, these quantification methods rely on assumptions about technology and travel behavior, which is an area with sparse empirical data but of high interest to agencies and communities looking ahead to future GHG emission reduction strategies. As the Bay Area begins to pilot these strategies at a regional-level, ARB staff will work with the region to collect program data that can inform future efforts in this emerging area.

ARB staff's review of MTC's climate initiative GHG emissions calculations is summarized below by strategy.

Regional Electric Vehicle Charger Program

Plan Bay Area's regional charger program aims to expand the region's public network of electric vehicle supply equipment (EVSE) for plug-in hybrid electric vehicles (PHEV). The network will allow electric vehicle drivers to increase their miles traveled in the vehicle's all-electric mode. Miles traveled using electricity

exclusively yield larger GHG benefits than miles traveled in the hybrid's gasoline mode.

To achieve this, the program helps overcome some of the cost barriers to EVSE installation. Financial assistance will be provided to interested employers, retailers, parking management companies, and others, for EVSE installation at workplaces, commuter hubs, and other destinations.

MTC estimates the program will reduce regional GHG emissions by 0.1 percent per capita from the 2005 baseline level by 2020, and 0.3 percent per capita by 2035. MTC estimated GHG emission reduction benefits by calculating the change in emissions with an increase in the all-electric mode miles traveled by PHEVs in the region.

Key assumptions in MTC's charger program analysis include: 1) there is no increase in total VMT or a shift in fleet make-up as a result of EVSE availability; 2) an increase from a baseline of 30 percent of PHEV travel miles as all-electric travel miles to 41 percent due to the regional charger program; and 3) that 20 to 25 percent of all PHEVs would require access to EVSE at any given time to achieve the increased electrification goal of this strategy.

ARB staff reviewed the fleet, VMT, and energy assumptions used in MTC's analysis of this strategy, and the method used to calculate the GHG emissions reductions of increasing all-electric mode miles traveled in the region. MTC's method and baseline assumptions are reasonable.

In the absence of existing data or other research, it is difficult to assess the reasonableness of MTC's assumption on the amount of EVSE stations or access needed to achieve a certain percent increase in all-electric travel miles by PHEV drivers. Data from implementation of this regional program is expected to provide better information for future analyses.

Vehicle Buyback and Plug-In Electric Vehicle Purchase Incentive

The objective of the regional vehicle buyback program is to accelerate fleet turnover in the Bay Area region toward more advanced and efficient plug-in hybrid electric or battery electric vehicles (BEV), by prompting demand among consumers who might otherwise either delay car purchasing, or buy a new or used conventional vehicle. The program will offer consumers who are willing to trade in older, less efficient vehicles, cash incentives toward the purchase of a new PHEV or BEV. Cash incentive amounts are expected to vary with the fuel economy of the vehicle being traded in, as well as the vehicle type being purchased.

MTC estimates the program will reduce regional GHG emissions by 0.5 percent per capita from the 2005 baseline level by 2035. MTC estimated emission reduction benefits by calculating the difference in emissions between a baseline fleet and a cleaner fleet, by decreasing vehicles older than ten years and replacing those vehicles with PEVs assumed to be deployed as part of the program.

While program details are still to be defined, key assumptions in MTC's greenhouse gas analysis include: 1) program implementation beginning in 2020; 2) an additional 47,000 PEVs on Bay Area roads attributable to the program, split 50/50 between PHEVs and BEVs; 3) buyback vehicles are more than ten years old; and 4) incentive levels of $1,000 per PHEV and $2,000 per BEV.

ARB staff reviewed the fleet, VMT, and energy assumptions used in MTC's strategy analysis, and the method used to calculate the GHG emissions reductions of incentivizing drivers of some of the region's older less efficient vehicles to replace them with PHEVs and BEVs. MTC's method and baseline assumptions are reasonable.

MTC assumes that an additional 47,000 PEVs will be attributable to this program. In the absence of existing data or other research, implementation of this regional program will be important to provide better information about the potential impact of buyback incentives on PHEV and BEV vehicle sales and the level of fuel economy improvements that can be achieved with displaced older vehicles.

Clean Vehicles Feebate Program

Feebates use a combination of fees and rebates to influence consumer purchasing behavior. MTC proposes establishing a regional feebate program, starting in 2020, where consumers who purchase vehicles emitting more GHG emissions per mile than a defined standard are assessed a fee at the point of purchase. Fees are used to provide consumers with rebates to purchase vehicles emitting less GHG emissions per mile than the defined standard. A regional clean vehicle feebate program would be the first of its kind in both the state and nation, and would likely require action by the State Legislature. In the near term, MTC plans to engage with ARB and the Bay Area Air Quality Management District (BAAQMD) to initiate its program development process.

While program details are still to be determined, MTC estimates a program like this can provide regional GHG emission reduction benefits of 0.7 percent per capita from its 2005 baseline by 2035. Emissions reductions were calculated by first estimating the improvement in average fuel economy of the region's new vehicle fleet between 2020 and 2035 due to a feebate program. A modified fuel economy was then estimated for the region's entire fleet between 2020 and 2035

and used to calculate a well-to-wheels differential in CO_2 emissions between the modified fleet and the baseline fleet.

Key assumptions in MTC's GHG analysis include: 1) the feebate program is introduced at the regional-level in 2020; 2) there are no increases in fuel economy standards at the state- or national-level after 2025; 3) the Bay Area represents about 20 percent of California's new car market; 4) a $20 per CO_2 grams/mile feebate rate; 5) as a result of the program, average CO_2 emissions for new vehicles sold in the region is reduced 10 grams/mile in 2020 and 2.5 grams/mile in 2035; and 6) the program is revenue neutral with administrative costs covered by MTC.

ARB staff reviewed the fleet, VMT, and energy assumptions used in MTC's strategy analysis, and the method used to calculate the GHG emissions reductions of incentivizing drivers to purchase cleaner vehicles with feebates. MTC's method and baseline assumptions are reasonable.

Data from implementation of this first in the nation regional program is expected to provide more information to support MTC's assumptions related to the expected percent change in average fleet GHG emissions under a feebate program. In its calculation, MTC assumes a selected value from a range of modeled results prepared by Bunch and Greene (2011) for ARB. MTC's approach is reasonable, but may be optimistic in light of California's Advanced Clean Cars (ACC) program, which includes more aggressive standards than were modeled in the Bunch and Greene (2011) study.

Smart Driving

Plan Bay Area's smart driving strategy is a public education campaign for the region's motorists that aims to reduce emissions by teaching techniques that change driving style, and by providing rebates for in-vehicle, real-time fuel efficiency gauges. This program targets emissions reductions from the existing stock of vehicles that will not be turned over for a zero emission vehicle in the near future. Examples of techniques that could be promoted include more regular vehicle maintenance and changes in driving style, like smooth acceleration and deceleration.

MTC estimates its smart driving program will achieve a 1.8 percent per capita GHG emissions reduction from the 2005 baseline in 2020 and a 1.5 percent per capita reduction in 2035. The emissions reductions decrease over time due to a number of factors including: the frontloaded impact of the program at the outset of the campaign when many drivers first adopt smart driving strategies, anticipated reduction in VMT, and increased vehicle fuel efficiency. MTC estimates emission reduction benefits for the program by calculating the number

of people anticipated to adopt the strategies advertised in the public education campaign and applying those estimations to the daily vehicle miles traveled.

Key assumptions in MTC's GHG analysis include: 1) a public education campaign focusing on four specific smart driving techniques -- smooth acceleration and deceleration and staying at or below the speed limit, linking of shopping trips, the use of trip planning applications, and the use of real-time, in-vehicle fuel efficiency meters; 2) based on a 2011 MTC survey, 10 percent of residents will implement the smart driving behaviors; 3) average daily miles traveled per vehicle would be 15.04 in 2020 and 13.8 in 2035;[14] and 4) adoption of one of the smart driving techniques does not interact with the GHG emissions reductions from the adoption of another smart driving technique.

ARB staff reviewed the assumptions regarding the effectiveness of the four smart driving techniques used in MTC's strategy analysis, and the method used to calculate the GHG emissions reductions from its smart driving campaign. In general, smart driving (also known as ecodriving) has been shown to reduce vehicle emissions. Due to the lack of recent, U.S.-based data on the effectiveness of smart driving/ecodriving the robustness of research on assumptions used in MTC's analysis about the efficacy of public education campaigns for smart driving/ecodriving techniques to the American context is lacking. The research that does address ecodriving/smart driving often refers to a variety of related measures and techniques that do not align directly with the public education campaign measures identified in Plan Bay Area. over time, data from implementation of the program is expected to help ARB staff better assess reasonableness of the effects of such a public campaign in future analyses.

Car Sharing

Car sharing is a short-term auto use program in which people rent cars for short periods of time, often by the hour. While reducing negative impacts of privately owned and operated vehicles, such as air pollution or congestion, car sharing provides a flexible transportation alternative to vehicle ownership for people that use a vehicle only occasionally. Fewer GHG emissions as a result of reduced VMT and reduced vehicle ownership are environmental benefits frequently associated with car sharing, as many trips shift from those typically made in a single occupancy vehicle, to walking, bicycling, and taking public transit. Studies

[14] As discussed with MTC and ICF.

show that with a car sharing option, people will choose alternatives to driving for shorter trips, while using the car sharing vehicle for occasional longer trips.

MTC estimates its car sharing program will achieve a 2.6 percent per capita reduction in GHG emissions by 2020 and a 2.6 percent per capita reduction by 2035. MTC estimates emission reduction benefits for the program by summing the estimated reductions in car share member VMT compared to non-car share members, and estimating the increases in car share member fuel efficiency, assuming that car share vehicles are more fuel efficient than the average vehicle.

Key assumptions in MTC's GHG quantification include: 1) there are currently over 60,500 car sharing members in traditional Bay Area car sharing systems; 2) car share members drive an average of seven fewer miles per day than non-car share members; 3) car share members drive approximately 1,200 miles per year in car share vehicles; 4) car share vehicles are more fuel efficient than the average vehicle, using approximately 29 percent less fuel per mile than the non-car sharing community through 2040; 5) the car share population in 2020 is 15 percent of the region's urban area population, and in 2035 it is 15 percent of the urban area population plus 5 percent of the suburban area population; and 6) there will be a constant, major shift in travel mode share to walking, bicycling, and taking public transit.

ARB staff reviewed the fleet, VMT, and energy assumptions used in MTC's strategy analysis, and the method used to calculate the GHG emissions reductions from expanding car share services in the region. MTC's method and baseline assumptions appear reasonable.

MTC's assumptions are based on several research studies that vary in sample size (number of participants), location (Bay Area, United States, Canada), and other survey characteristics. While the individual research results analyze demographics and travel behavior of a defined sample, linking those results and driving assumptions to Bay Area conditions is challenging. Data from implementation of a car sharing program at the regional level is expected to provide more information on the rate of participation in car sharing as a mode of travel, and the potential for behavioral change. This information will be useful for future analysis.

Commuter Benefit Ordinance

MTC and the Bay Area Air Quality Management District (BAAQMD) are now in the process of jointly developing a regional commuter benefit ordinance. This program is expected to require employers with 50 or more full-time Bay Area employees to offer their employees incentives to use a mode other than driving alone while commuting to and from work. With the legislative authority (SB 1339) to implement this region-wide ordinance already in place, this strategy is

projected to decrease VMT by shifting some employees from driving alone to using transit, vanpools, carpools, or active transportation modes.

MTC estimates the ordinance would achieve GHG emissions reductions of 0.1 percent per capita in 2020, and 0.3 percent per capita in 2035, compared to a 2005 baseline. MTC calculated GHG emissions reductions by first estimating the number of businesses with at least 50 employees, then the number of single occupancy vehicle (SOV) commute tours attributable to those businesses, taking only 54 percent of those tours to account for the assumed 46 percent of employers who already offer a commuter benefit program, and using that to calculate the daily number of trips shifted from SOV to transit. This number of trips is then used to calculate the daily reduction in VMT, which is an input to EMFAC2011 used to obtain the amount of CO_2 projected to be reduced.

While several incentive options are available, for the sake of calculating the GHG emission reduction benefits, Plan Bay Area assumes that all employers in the program will provide the lowest cost option to their employees, and estimates the change in commute VMT associated with this option, allowing employees to pay for transit, vanpooling, and/or bicycle expenses using pre-tax income. Other incentive options are also available to employers.

Additional key assumptions in MTC's GHG analysis include: 1) an elasticity of 0.15 (that is, for every one percent reduction in transit cost, there would be a 0.15 percent reduction in the number of single occupancy vehicle commuters on the road), 2) that the pre-tax benefit would result in a 33 percent transit cost reduction, 3) that 46 percent of employers already offer one of the required benefits prior to implementation of the ordinance, and 4) in the interest of simplifying calculations, employees who take advantage of these incentives would all shift from SOV modes to modes that wouldn't result in new vehicle trips.

ARB staff reviewed MTC's assumptions regarding the estimates for VMT reductions and the method used to calculate GHG emissions reductions and finds them generally reasonable. One exception is with respect to the elasticity that MTC chose. While MTC cited a long-term elasticity from Litman's 2004 literature review, they have used a short-term elasticity. In addition, MTC mischaracterized the elasticity as directly relating auto trips with transit fares. According to Litman's paper, only ten to 50 percent of the rise in bus ridership resulting from reduced fares can be substituted for automobile trips. The end result of these two differences with the cited Litman study is that, while MTC's VMT reduction estimates still fall within Litman's cited range, MTC's estimate is closer to the middle of the range, rather than at the low end, as they state in their off-model documentation.

Still, there is a limited amount of research available to draw upon in assessing the reasonableness of MTC's elasticity assumption. Data that could be generated from the implementation of this program is expected to provide better information for future analyses.

Vanpools

Plan Bay Area calls for additional resources to MTC's existing vanpool program, with the goal of increasing vanpool ridership, which is expected to reduce the number of single occupancy vehicles on the road, and therefore, VMT. To achieve this goal, MTC plans to increase the subsidy given to vanpools to $400 per month per van, from the current one-time $500 start-up subsidy, up to $100 per year when a passenger drops out of a vanpool, and free bridge tolls.

MTC estimated that the vanpooling program will reduce regional GHG emissions by 0.3 percent per capita from the 2005 baseline by 2020, and 0.4 percent per capita by 2035. MTC estimated these GHG emissions reductions by calculating the daily VMT expected to be traveled by commuters who would be new participants in vanpools, the number of trips per day eliminated by future vanpool participants who are no longer driving alone or in two- or three-person carpools, and the emissions from the eliminated VMT and trips, using EMFAC 2011.

Key assumptions that MTC's GHG quantification of the vanpool program relies upon are that 1) the vanpool fleet will double from the current 515 vans with over 5,500 daily participants to 1030 vans; 2) the average of 10.8 passengers and the roundtrip distance of 116 miles per van will remain constant over time; and 3) to account for the emissions of the vans themselves, an average of 9.8 passengers will be used in the calculations.

ARB staff reviewed the expected increase in the vanpool fleet and the method used to calculate the GHG emissions reductions from an increase in the vanpool fleet. MTC's method and baseline assumptions are reasonable.

D. Model Sensitivity Analysis

The use of sensitivity analyses is intended to provide an indication on how an MPO travel demand model actually behaves, compared to how it is expected to behave, and whether the model is capable of producing forecasts that could reasonably be expected to result from the data inputs and assumptions used. The analyses usually involve systematically changing one model input variable at a time (e.g. increases in transit frequency, roadway pricing, land uses) to see how sensitive the model outputs, such as VMT, are to changes in the input variable. However, sensitivity analyses are not intended to quantify model inputs or outputs or provide an analysis of actual modeled data. They are simply intended to assess the performance of the model itself.

Travel modelers will typically rate models as being sensitive as long as changes in model outputs result from changes in model inputs. ARB's analysis goes further by asking whether or not the results of the SCS sensitivity analysis demonstrate that the model is showing output changes that are within the range of values published in relevant empirical literature. In those cases where there was a lack of empirical literature with which to corroborate MTC's sensitivity analysis findings, ARB staff would simply indicate that the findings were or were not sensitive, depending upon whether changes in model inputs resulted in changes to model outputs. In those instances 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.

ARB requested that MTC conduct a series of sensitivity analyses for its model using the following variables:

- Combined household income, residential density, and employment density
- Auto operating cost
- Express lane pricing
- Transit service frequency, BART only

MTC's sensitivity analyses were evaluated to understand how its travel demand model outputs changed as the network, land use, or transportation-related inputs changed. Changes in model outputs were compared with expected changes indicated in the empirical literature. In those cases where the range of elasticities[15] was available in the literature, ARB applied them to changes in model inputs that were used in MTC's sensitivity analyses. Results of these sensitivity analyses provided a better understanding of the travel demand model's capacity to effectively capture the GHG emissions impacts of MTC's SCS on key model outputs such as VMT, trips, and mode share.

Following is a summary of the evaluation of the sensitivity analyses that are reported by MTC. We note that neither the sensitivity analyses, nor pertinent findings in the empirical literature, are in all cases definitive. The integration of sustainable community strategies into transportation modeling is still relatively new, resulting in analytical knowledge gaps that experience and new research will overcome over time. Nevertheless, the results of MTC's sensitivity analyses are complete and generally consistent with available empirical literature.

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

Based on both MTC's specific sensitivity analyses, and examination of the relevant empirical literature, ARB staff's evaluation shows that MTC's analysis of model output changes are directionally consistent, and that the model is generally sensitive for the variables tested. MTC's analysis reflected changes to model outputs from changes in inputs. For many of the variables, MTC's results were consistent with the empirical literature. In some cases, no comparable empirical studies were available which examined the same inputs and outputs as MTC's analysis. Such a comparison would help ensure that staff's analysis is technically sound. In four instances, MTC's results were slightly outside the lower range of expected impacts based on the literature. These instances are explained in more detail in the following sections, with explanations of factors that may have affected the sensitivity test results.

1. Combined Household Income, Residential Density, and Employment Density

MTC modeled three variables, combined household income, residential density, and employment density, together. As expected, MTC's travel model showed that VMT would increase with increases in household income, and that VMT would decrease with increases in residential density and employment density. MTC staff computed the elasticity for each of these three variables by using the univariate regression coefficient and the sample means.

Household Income Sensitivity Analysis

There is relatively little in the empirical literature that cites the direct effect of income on household VMT. Murakami and Young (1997) 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. MTC's sensitivity analysis showed a computed elasticity of 0.166. The model shows that it is sensitive to changes in household income levels; the changes are moving in the right 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.

Residential Density Sensitivity Analysis

Most of the studies cited in the empirical literature that relate to residential density focus on overall population density, and is probably the best proxy for residential density. The elasticities for the impacts of population density on VMT cited in the studies range from -0.05 to -0.12 (Boarnet and Handy, 2013). MTC's sensitivity analysis showed an estimated elasticity of -0.063, which indicates that the model is sensitive directionally and in magnitude to changes in residential density; the changes are moving in the right direction (i.e. higher residential densities result in lower VMT), and MTC's estimated elasticity falls within the range of elasticities cited in the empirical literature.

Employment Density

One way to examine the impacts of changes to employment density is with jobs-housing balance data. In other words, researchers consider the impacts to employment density if the number of jobs relative to housing is increased or decreased. Another proxy for employment density is land use mix since, by definition, it presumes the addition of commercial land use (with corresponding employment) in residential areas. MTC's sensitivity analysis showed an estimated elasticity of -0.103. The model shows that it is directionally sensitive to changes in employment density (i.e. greater employment density results in fewer VMT), however, because MTC's sensitivity test was not based on either jobs-housing balance or on land use mix, directly relevant empirical literature could not be identified.

2. Auto Operating Cost

MTC conducted five sensitivity tests to determine the model's responsiveness with respect to changes in auto operating cost. In these tests, auto operating costs were changed to 50, 79, 100 and 300 percent of the 2000 baseline auto operating cost of $0.14 per mile (in 2000 dollars). MTC refers to the operating cost as perceived because of uncertainty about what an individual traveler assumes the cost to be; therefore, MTC assumes every resident in the region behaves as if traveling one mile in their car costs 14 cents. MTC staff assumed that fuel cost has the greatest influence on perceived auto operating cost, therefore test results were compared to the available empirical literature on changes in fuel costs.

When auto operating cost increases, travelers are expected to drive less and/or make shorter distance trips, resulting in VMT decreases. When auto operating cost decreases, VMT is expected to increase. The empirical literature includes elasticities that range from -0.02 to -0.09 (Small and Van Dender, 2007) and -0.15 (Agras and Chapman, 1999) for changes in vehicle travel over the short-run (less than five years) relative to fuel price. The long-run elasticities (greater than five years) from these studies are -0.11 to -0.34 (Small and Van Dender, 2007) and -0.32 (Agras and Chapman, 1999).

Table 26 summarizes the modeled VMT resulting from various auto operating costs. When operating cost was dropped to 79 percent of the base case cost, VMT increased by 10 percent. Conversely, when auto operating cost was increased to 300 percent above the base case, VMT decreased by 22 percent. All the modeled VMT fall within the expected short-run VMT ranges; but the modeled VMT associated with 100 and 300 percent increases in auto operating cost do not fall within the expected long-run VMT ranges, which possibly means that the change of 100 and 300 percent in auto operating cost are outside the applicable range of change in auto operating cost in the existing literature.

Table 26. Auto Operating Cost - Sensitivity Test Results

Test	Auto Operating Cost*	Modeled VMT (thousands)	% Change in VMT from Base Case	Expected Short-Run VMT Range† (thousands)	Expected Long-Run VMT Range§ (thousands)
79 percent decrease from base case cost	$0.03	188,555	10%	174,535 - 192,087	186,686 - 217,739
50 percent decrease from base case cost	$0.07	182,197	6%	173,553 - 184,723	181,286 - 201,047
Base case	$0.14	171,835	0%	--	--
100 percent increase from base case cost	$0.28	155,064	-10%	146,060 - 168,398	113,411 - 152,933
300 percent increase from base case cost	$0.56	133,344	-22%	94,509 - 161,525	0 - 115,129

*In 2000 dollars.

†Calculated based on short-run elasticities of -0.02 to -0.15

§Calculated based on long-run elasticities of -0.11 to -0.34

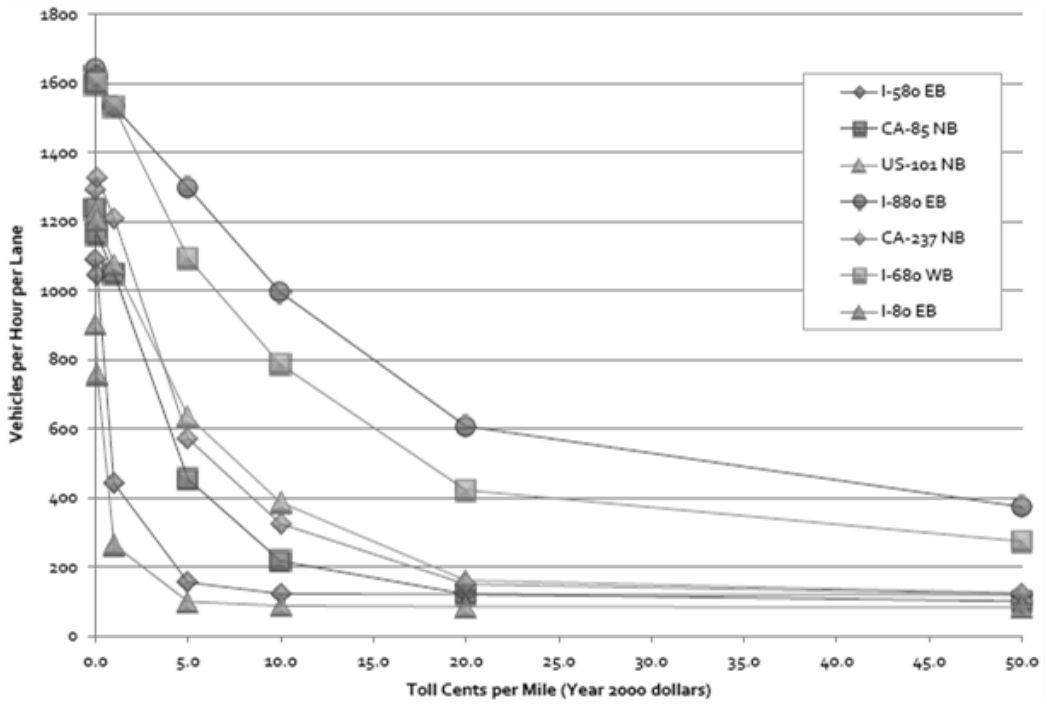
3. Express Lane Pricing

Express lanes, also known as high-occupancy toll (HOT) lanes, are high occupancy vehicle (HOV) lanes that give solo drivers the option of paying a fee to use the lanes, while vehicles with two or three occupants may use them free of charge. The intent of express lanes is to increase the efficiency of underused HOV lanes and ease congestion in the general purpose lanes.

MTC performed seven sensitivity tests varying the charge for the use of express lanes for low-occupancy vehicles (i.e. drive alone and 2-person carpools) to examine the responsiveness of its travel demand model to the change of express lane pricing. In these tests, the year 2035 scenario with an extensive express lane network served as the base case. MTC staff tested the model with the express lane price set at 0, 0.1, 1, 5, 10, 20, and 50 cents per mile.

As the toll price increases, there would be an expected decrease in usage and an increase in speed on the express lanes, and there would be a corresponding increase in usage and decrease in speed on the general purpose lanes. Figure 12 shows one of the three model results of average volume on the express lane during the morning commute peak period, as reported by MTC. The trends in Figure 12 are consistent with expectations – as the toll price increases from 0 to 50 cents per mile, hourly volume on the express lanes decreases.

Figure 12. Average Morning Commute Peak One Hour Express Vehicles per Lane



Source: MTC with Parsons Brinckerhoff, Inc. (2013), *Travel Model Development: Sensitivity Testing*.

It is also expected that the drive alone mode share would increase when the toll price is set between 0 cents per mile and the break-even price, at which the benefit of using the express lane is the same as the cost of the toll price. The reported percent mode share results for drive alone (DA), 2-person carpool (S2), 3-person carpool (S3), walk/bike, and transit with respect the change of toll price are summarized in Table .

Table 27. Percent Mode Share – Sensitivity Test Results

Mode	Toll Price (cents/mile)						
	0	0.1	1	5	10	20	50
DA	49.8%	50.1%	50.1%	49.9%	49.8%	49.7%	49.7%
S2	17.7%	17.9%	17.9%	17.9%	17.9%	17.9%	17.8%
S3	13.2%	12.9%	12.9%	13.0%	13.0%	13.1%	13.3%
Walk/Bike	12.7%	12.7%	12.7%	12.7%	12.7%	12.7%	12.7%
Transit	6.6%	6.5%	6.5%	6.5%	6.5%	6.6%	6.6%

As expected, when the toll price increases from 0 to 1 cent per mile, the percent mode share of DA increases slightly. When the toll price is higher than 1 cent per mile, the percent mode share of DA or S2 starts to reduce slightly because the benefit of travel time saving is less than the cost of the toll. Because S3 users could access the express lane free of charge, their response to the change in toll price is almost irrelevant. Because the implementation of toll price would directly affect highway traffic but not non-motorized trips, the response of walk/bike and transit is unchanged with changes in toll price.

4. Transit Service Frequency, Bay Area Rapid Transit (BART)

MTC conducted sensitivity tests to determine the model's responsiveness to the BART system's service frequency. MTC used a year 2010 baseline of 15 minute service frequency and ran sensitivity tests of 5, 10, 20, and 25 minute service frequencies for BART (Table). Based on MTC's model runs at 5 and 10 minute frequencies, ridership increased 26.9 percent and 11.5 percent, respectively, from the baseline. At 20 and 25 minute frequencies, ridership decreased 6.53 percent and 12.42 percent, respectively. The elasticities generated from the model range from 0.46 to -0.62 indicating that the model is directionally sensitive to changes in transit service levels (i.e. more transit service results in more transit ridership), but the degree of change is not entirely consistent with the elasticities from the empirical literature. MTC explains this by saying that this sensitivity test only changes BART's frequency but does not include changes made to all the transit feeder systems to BART.

Table 28. MTC's BART Frequency Sensitivity Analysis Results

Frequency (minutes)	5	10	15	20	25
Trains per Hour	12	6	4	3	2.4
Modeled Ridership	437,227	386,318	346,473	323,860	303,441
Modeled Elasticity	0.10	0.46	--	-0.50	-0.62
Percent change in ridership from Baseline	26.19%	11.50%	--	-6.53%	-12.42%
Anticipated Ridership (based on 0.5 elasticity (Handy et al., 2013))	692,946	433,091	--	303,164	277,178
Anticipated Change in Ridership from Baseline	100%	25%	--	-13%	-20%

E. SCS Performance Indicators

ARB staff evaluated changes in a set of key indicators that describe SCS performance. These indicators are examined to determine if they can provide qualitative evidence that the SCS could meet its GHG targets if implemented. ARB staff evaluated the directional consistency of the indicators with MTC's modeled GHG emissions reductions, as well as the general relationships between those indicators and GHG emissions identified in the empirical literature. The indicators include: residential density, housing type mix, housing units in PDAs, passenger VMT, mode share, and average trip length. The assessment relies on key empirical studies for each indicator that illustrate qualitatively that changes can increase or decrease VMT and/or GHG emissions. Below is a summary of the evaluation for the land use and transportation-related performance indicators.

1. Land Use Indicators

To determine the benefits of the development pattern in the RTP/SCS on GHG emissions from passenger vehicles, the evaluation focused on the following performance indicators related to land use: residential density, housing type mix, and housing units in PDAs.

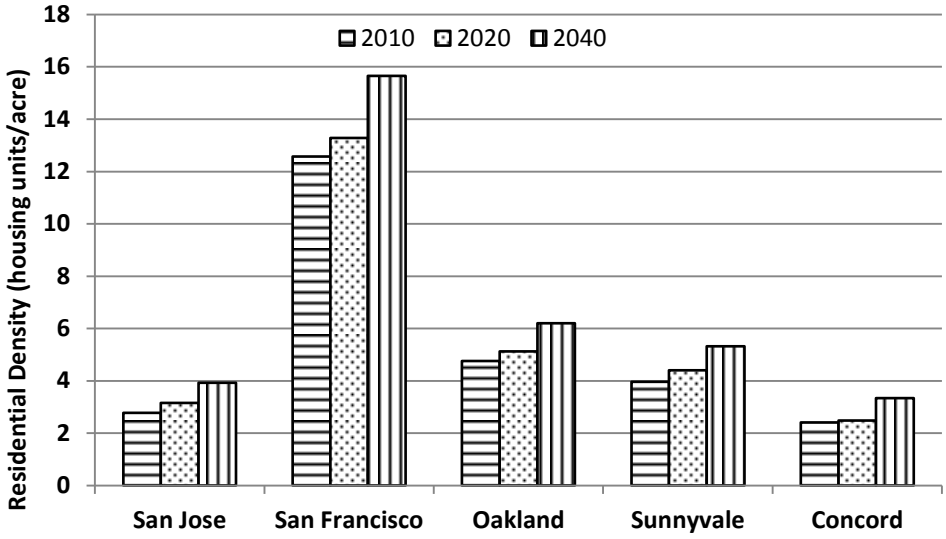
Residential Density

Residential density is a measure of the average number of dwelling units per acre of developed land. Travel characteristics in the region are expected to change as the housing market shifts from single family homes to multi-family housing units. These changes in travel behavior include reductions in average trip length, and could eventually result in decreased regional VMT.

A review of relevant empirical literature reveals that increases in density could reduce VMT. Brownstone and Golob (2009) analyzed National Household Travel Survey (NHTS) data and observed that denser housing development significantly reduces annual vehicle mileage and fuel consumption, which directly results in lower GHG emissions. They also reported that households in areas with 1,000 or more units per square mile drive 1,171 fewer miles and consume 64.7 fewer gallons of fuel than households in less dense areas. Boarnet and Handy (2013) reported that doubling residential density reduces VMT an average of 5 to 12 percent. Litman (2013) reported that a 1 percent increase in population density leads to a 0.2 to 1.45 percent decrease in the demand for car travel.

ABAG/MTC's land use forecast in the final plan projects that between 2010 and 2020 the region's residential density will increase by about 5 percent, and between 2010 and 2040, it will increase by about 19 percent. Figure 13 shows residential density in the five cities in the nine-county region expected to experience the most housing growth between 2010 and 2040. For example, San Jose will have about 130,000 new housing units by 2040. The trend in increased residential density supports the forecasted GHG reductions.

Figure 13. Residential Density in Top Five Cities in Bay Area

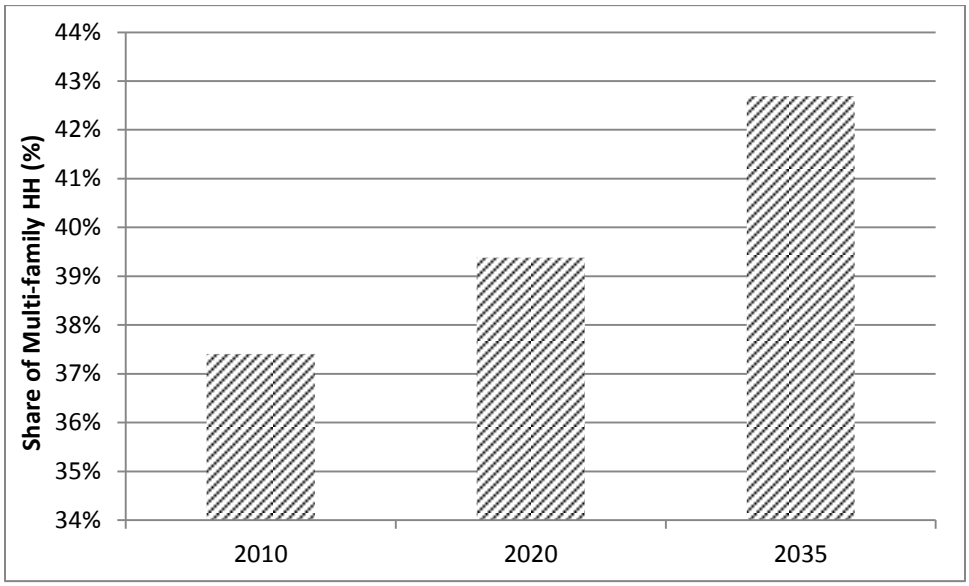


Housing Type Mix

Housing type mix influences what land use patterns can be achieved in a region. The greater the proportion of housing growth that is multi-family development, the more opportunity a region has to accommodate future growth through a more compact land use pattern.

Between 2010 and 2035, Plan Bay Area shows an increase in multi-family households relative to the total number of households from 37 percent to 43 percent (Figure 14) because housing changes occur over the long-term. Projected demographic changes and increased racial and ethnic diversity are anticipated to cause the shift to new multi-family units. By 2040, the region's share of senior citizens will increase to 22 percent from today's 12 percent, and Latinos are expected to emerge as the largest ethnic group. Of the new households in the region since 2010, multi-family households are estimated to grow by about 62 percent by 2020, and 66 percent by 2035. This trend further supports the forecasted GHG emissions reductions.

Figure 14. Share of Multi-Family Housing Units in the Region

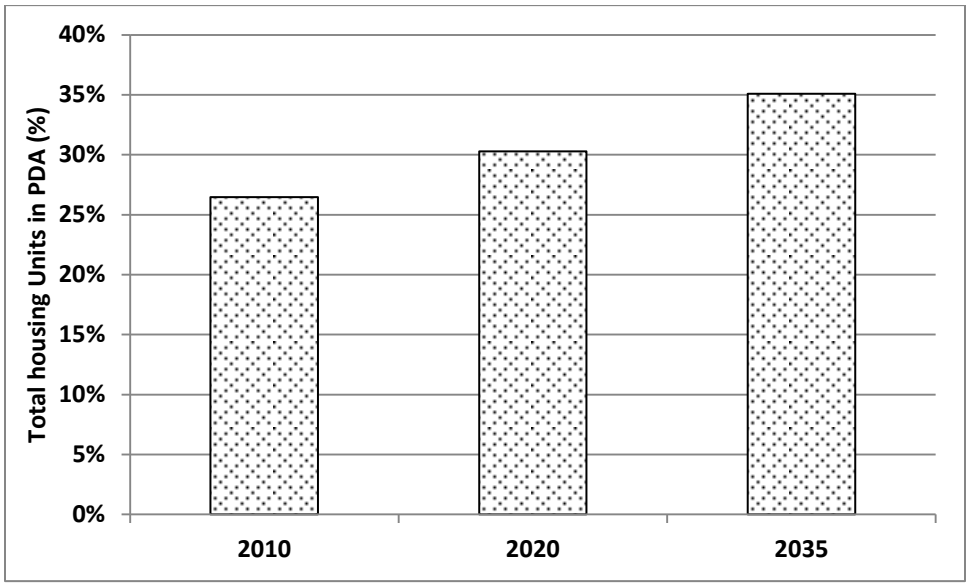


Housing Units in PDAs

In developing the future land use pattern, ABAG/MTC assumed about 78 percent of new housing and 62 percent of employment development would occur within areas close to transit, which are identified as PDAs. Focusing new growth in areas with good access to frequent transit service is a key SCS measure that ABAG/MTC hopes will encourage transit ridership and reduce or eliminate the need for vehicle trips, increase the use of walking or biking, and maximize the benefits of a denser, more compact land use pattern.

Relevant empirical literature provides supporting evidence for the reduction trend ABAG/MTC anticipates in GHG emissions. Proximity of housing and employment to transit is a commonly-used performance measure for evaluating the effectiveness of transit oriented development (TOD). The empirical literature indicates that commuters living within a TOD area use transit two to five times more than do other commuters in the region. Moreover, the literature shows that proximity of housing and employment to transit stations is highly correlated with increased transit ridership. Transit ridership sharply increases as housing and employment increases within a one mile radius of transit stations (Kolko 2011). Other studies show significant VMT reductions for placement of housing and employment closer to rail stations and bus stops (Handy, et.al 2013). In the ABAG/MTC region, the percentage of housing units in PDAs was 26 percent in 2010. ABAG/MTC projects that this will increase to nearly 30 percent in 2020 and nearly 35 percent in 2035 (Figure 15). The anticipated increase in housing units near transit stations/stops provides additional supportive evidence for the reported reduction trend in GHG emissions in the region.

Figure 15. Percentage of Housing Units in PDA



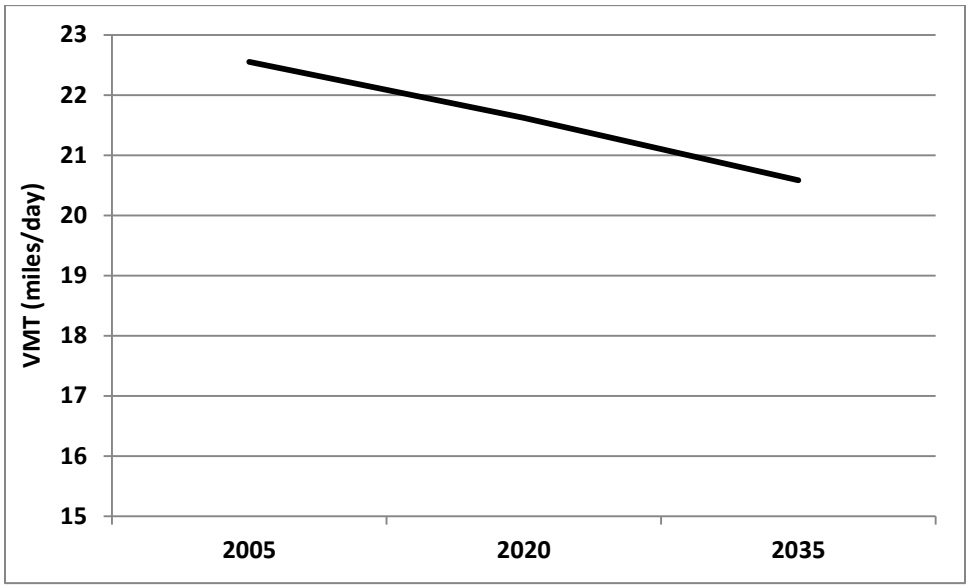
2. Transportation-Related Indicators

ARB staff evaluated three transportation-related performance indicators along with supporting data inputs, assumptions, and sensitivity analyses. These indicators are passenger VMT, mode share, and average trip length.

Passenger Vehicle Miles Traveled

Plan Bay Area, as expected, shows a decline in per capita passenger vehicle VMT over time. VMT per capita decreases by 4.1 percent between 2005 and 2020 and 8.7 percent between 2005 and 2035, as shown in Figure 16. The quantification of GHG emissions from passenger vehicles is a function of both VMT and vehicle speeds. These results are directionally consistent with and supportive of the reported GHG emission reduction trend over time.

Figure 16. Per Capita Passenger VMT Trends

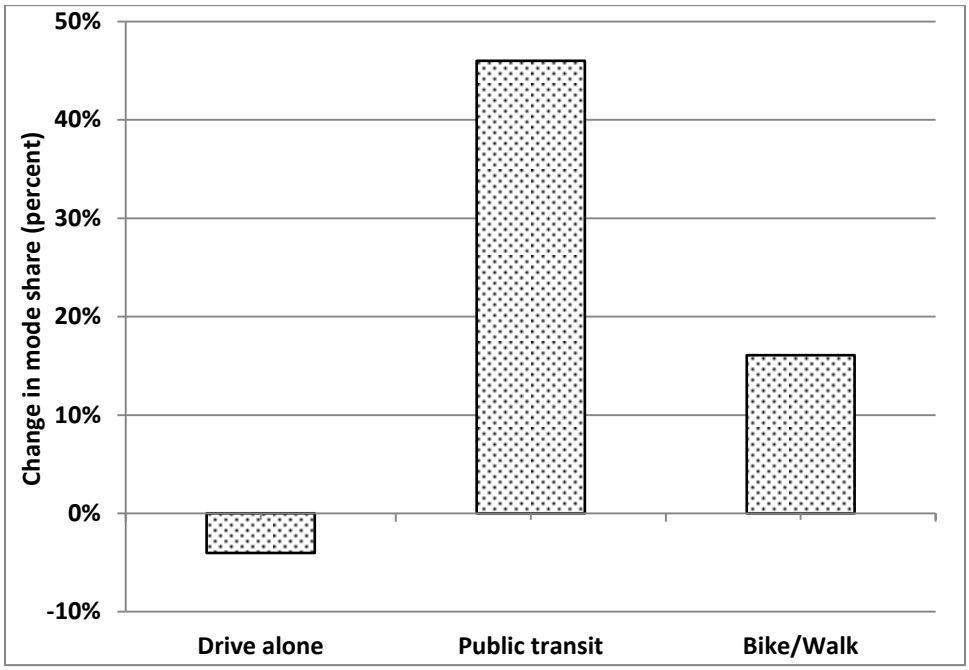


Mode Share

Mode share measures the change over time in the means by which people travel. Shifting trips from vehicle to non-vehicle modes (e.g. bike, walk, working at home) reduce vehicle GHG emissions in a region. While a change in mode shares cannot generally be used to quantify a change in GHG emissions, the empirical literature indicate that GHG emissions per person are likely to decrease as automobile mode share decreases and transit, bike, and walk mode shares increase.

Mode share is included for both commute and non-commute trips, measuring how people travel from home-to-work and back, as well as how they travel for school, shopping, personal business, and all other non-work trip purposes. Figure 17 shows the expected percent change in mode share by 2035 with respect to 2005 for all trips. Since 2005, the drive alone mode share decreases about 4 percent. Bike/walk and transit mode shares increase by 16 percent and 46 percent, respectively. The increase in transit ridership and bike/walk are also due to an increase in density of the population. These results are directionally consistent with and supportive of the reported GHG emission reduction trend over time.

Figure 17. Percent Change in Mode Share by 2035 (all trips)

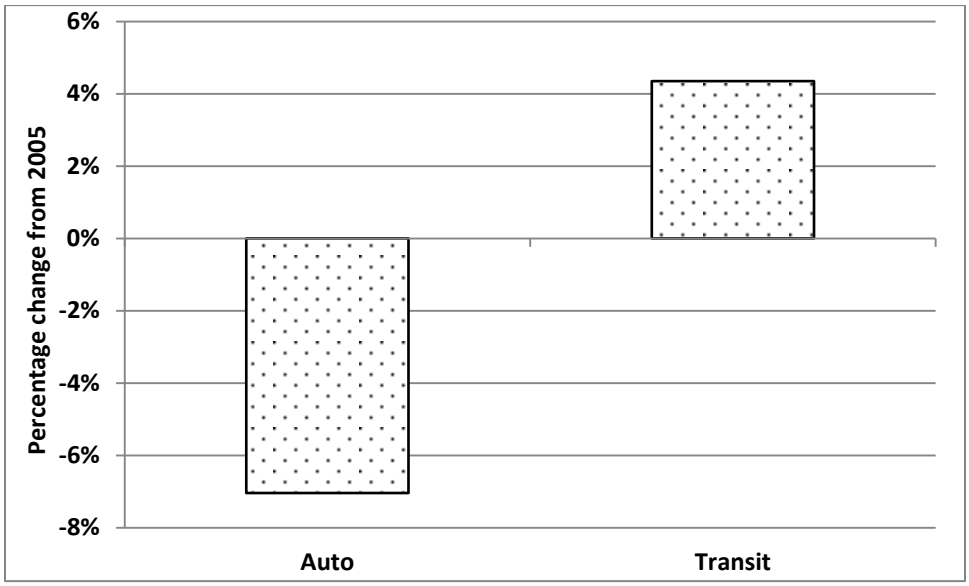


Average Trip Length

Changes in the average trip length by mode can contribute to an overall reduction of GHG emissions in a region. Decreases in average trip length for trips by auto can reduce a region's GHG emissions by decreasing overall miles traveled in a vehicle. An increase in average trip length for trips by transit modes can also contribute to the reduction of GHG emissions.

Figure 18 shows the change in average trip length by mode for all trip purposes as reported by MTC. The data shows that the average automobile trip length decreases by 7 percent, from 7.1 miles in 2005 to 6.6 miles in 2040. During the same time period, average trip length for transit increases 4.3 percent from 9.2 miles in 2005 to 9.6 miles in 2040. These trends are directionally consistent with and supportive of the reported GHG emission reduction trend.

Figure 18. Average trip length by mode by 2040



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APPENDIX A. MTC's Modeling Data Table

This appendix contains MTC's responses to data requests, received February 18, 2014 to supplement staff's evaluation of MTC's quantification of GHG emissions. The requests are consistent with the evaluation methodology.

Modeling Parameters[16]	2005 (if available)	2010 (base year)	2020		2035 (Project)	2040		RTP SCS Chapter-Page(s)[17]
			(Without Project)[18]	(With Project)		(Without Project)	(With Project)	
DEMOGRAPHIC								
Total population (control) -- excludes institutionalized group quarters population	7,096,469	7,150,741	7,718,418	7,718,420	8,794,967	9,195,569	9,195,546	ARB[19]; PTS[20] 14
Total population (simulated) -- excludes institutionalized group quarters population	7,007,634	7,053,334	7,696,761	7,697,101	8,744,154	8,709,541	9,133,090	ARB; PTS[21] 14
Group quarters population (control) – excludes institutionalized group quarters population	144,597	147,683	93,971	93,956	103,958	110,665	110,627	ARB; PTS 14
Total number of households (control)	2,583,077	2,608,023	2,833,696	2,837,715	3,188,328	3,308,120	3,308,111	ARB; PTS 14
Total number of households (simulated) – includes group quarters	2,720,722	2,732,722	2,894,543	2,925,108	3,285,177	3,281,324	3,411,297	ARB; PTS 14
Persons per household (control) – excludes group quarters	2.69	2.69	2.69	2.69	2.73	2.75	2.75	ARB
Auto ownership per household (simulated)	1.78	1.78	1.79	1.80	n/a	1.78	1.75	ARB

[16] When reporting $ units, indicate what year $s.
[17] If not in RTP/SCS, please indicate other referenced data source (other planning documents, model runs, etc.)
[18] This scenario includes existing plus committed transportation projects/policies for respective calendar years and a no project land use pattern.
[19] Information compiled specifically for ARB
[20] Information can be found in the *Summary of Predicted Traveler Responses* supplementary report
[21] Information can be found in the *Summary of Predicted Traveler Responses* supplementary report

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035 (Project)	2040		RTP SCS Chapter-Page(s)
			(Without Project)	(With Project)		(Without Project)	(With Project)	
Total jobs	3,449,640	3,385,281	3,959,089	3,987,130	4,346,745	4,473,934	4,505,232	ARB; p 32
Employed Residents (control)	3,225,106	3,153,267	3,891,142	3,849,814	4,198,398	4,364,374	4,350,068	ARB
Average unemployment rate (%)		10.6	5.1	5.1	5.1	5.1	5.1	Draft Forecast[22] p 6
Average household income (2009$)	$ 107,343	$ 99,426		$ 96,539	$ 93,604		$ 93,261	ARB
LAND USE								
Total agricultural (farmland) acres[23]	---[24]	2,329,000	---	---	---	2,312,038	2,323,087	DEIR, 3.1-50
Total Williamson Act land acres	---	1,252,500	---	---	---	1,247,834	1,251,776	DEIR, 3.1-51
Total open space acres	---	1,015,000	---	---	---	1,013,090	1,012,605	DEIR, 3.1-51/52
Total forest and timberland acres	---	1,233,000	---	---	---	1,230,423	1,231,605	DEIR, 3.1-53
Total acreage available for new development	---	---	---	---	---	---	---	---
Total dwelling units	---	2,785,948	---	2,955,948	3,321,190	---	3,445,950	PBA[25] p 57, ARB
Total agricultural (farmland) acres[26]	---	2,329,000	---	---	---	2,312,038	2,323,087	DEIR, 3.1-50
Total Williamson Act land acres	---	1,252,500	---	---	---	1,247,834	1,251,776	DEIR, 3.1-51

[22] Information can be found in the *Draft Plan Bay Area Forecast of Jobs, Housing, and Population* supplementary report
[23] Agricultural, Williamson Act, open space and forest/timberland includes double counting, so the rows total to more than the Total Acres row.
[24] Not readily available and/or not relevant
[25] Information can be found in the *Plan Bay Area* report
[26] Agricultural, Williamson Act, open space and forest/timberland includes double counting, so the rows total to more than the Total Acres row.

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035 (Project)	2040		RTP SCS Chapter-Page(s)
			(Without Project)	(With Project)		(Without Project)	(With Project)	
Regional housing vacancy rate (%)	---	6.4	---	4.0	4.0	---	4.0	Draft Forecast p 6
Households in single family detached and attached dwellings	1,637,119	1,632,549	1,747,902	1,720,196	1,827,195	1,850,263	1,863,707	ARB
Total single family attached housing units	---	---	---	---	---	---	---	---
Total large-lot single family detached housing units	---	---	---	---	---	---	---	---
Total small-lot single family detached housing units	---	---	---	---	---	---	---	---
Households in multi-family dwellings	945,958	975,474	1,065,344	1,117,519	1,361,133	1,349,136	1,444,404	ARB
Total townhouse units	---	---	---	---	---	---	---	---
Total mobile home units	---	---	---	---	---	---	---	---
Total infill housing units	---	---	---	---	---	---	---	---
Share of housing units within ¼ mile of a transit station or stop	---	69%	---	---	---	67%	73%	ARB
Share of housing units within 1/3 mile of a transit station or stop	---	79%	---	---	---	76%	83%	ARB
Share of housing units within ½ mile of a transit station or stop	---	89%	---	---	---	85%	92%	ARB
Share of housing units within 2/3 mile of a transit station or stop	---	93%	---	---	---	89%	95%	ARB
Total housing units within PDAs[27]	---	725,071	---	871,984	1,142,239	---	1,234,635	ARB
New housing units within PDAs	---	---	---	146,916	417,171	---	509,567	ARB
Total employment (employees) within 1/4 mile of transit stations and stops	---	---	---	---	---	---	---	---

[27] For metrics related to Priority Development Area (PDA), use definition of PDA as per MTC's proposed RTP/SCS.

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035 (Project)	2040		RTP SCS Chapter-Page(s)
			(Without Project)	(With Project)		(Without Project)	(With Project)	
New employment (employees) within 1/4 mile of transit stations and stops	---	---	---	---	---	---	---	---
Total employment (employees) within 1/2 mile of transit stations and stops	---	---	---	---	---	---	---	---
New employment (employees) within 1/2 mile of transit stations and stops	---	---	---	---	---	---	---	---
Total employment (employees) within PDAs	---	1,478,507	1,848,293	1,830,855	2,062,151	2,167,411	2,164,260	ARB
New employment (employees) within PDAs	---	---	278,385	352,348	583,644	597,503	685,753	ARB
Average residential density - housing units per developed residential acre (Region)	4.2	4.2	4.5	4.4	4.8	5.0	5.0	ARB
TRANSPORTATION SYSTEM								
Freeway general purpose lanes –- mixed flow(lane miles)	---	---	---	---	---	---	---	---
Freeway-to-freeway connector lane miles	---	176	---	---	---	174	173	ARB
Freeway lane miles (including managed lanes and auxiliary lanes)	---	4,667	---	---	---	4,974	5,219	ARB
HOV lane miles	---	474	---	---	---	315	201	ARB
Express lane miles	---	14	---	---	---	410	720	ARB
Freeway auxiliary lanes (lane miles)	---	---	---	---	---	---	---	---
Freeway new ramps or widened ramps (lane miles)	---	---	---	---	---	---	---	---
Arterial (lane miles)	---	8,710	---	---	---	8,767	8,749	ARB; EIR 2.1-27
Minor Arterial (lane miles)	---	---	---	---	---	---	---	---
Collectors (lane miles)	---	5,582	---	---	---	5,548	5,502	ARB; EIR 2.1-27
Locals (lane miles)	---	---	---	---	---	---	---	---
Local and express bus seat miles	22,176,000	21,019,000	21,354,000	23,300,000	23,459,000	21,662,000	23,435,000	ARB

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035 (Project)	2040		RTP SCS Chapter-Page(s)
			(Without Project)	(With Project)		(Without Project)	(With Project)	
Light Rail Seat Miles	3,754,000	4,057,000	4,108,000	5,329,000	5,391,000	4,424,000	5,391,000	ARB
Heavy Rail Seat Miles	19,874,000	22,067,000	25,204,000	25,082,000	28,372,000	26,545,000	28,372,000	ARB
Commuter Rail Seat Miles	7,947,252	7,232,000	9,139,000	11,421,000	11,421,000	9,139,000	11,421,000	ARB
Transit total daily vehicle seat miles	56,098,000	56,681,000	62,713,000	68,681,000	72,192,000	64,680,000	72,168,000	ARB
Bicycle and pedestrian (Class I) lane miles	---	---	---	---	---	---	---	---
Bike lane miles (Class II)	---	---	---	---	---	---	---	---
Miles of sidewalk	---	---	---	---	---	---	---	---
ACTIVITY PATTERN SHARE FOR FULL-TIME WORKERS								
Mandatory	82.4%	82.3%	80.5%	80.6%	---	76.7%	76.9%	ARB
Non-mandatory	10.0%	9.9%	10.6%	10.6%	---	12.6%	12.3%	ARB
Home (incl. telecommuting)	7.7%	7.8%	8.8%	8.8%	---	10.7%	10.7%	ARB
TOUR & TRIP DATA								
Number of trips per day	23,593,000	23,420,000	25,500,000	25,412,000	---	28,383,000	29,422,000	ARB
Trips on mandatory tours	10,391,000	10,159,000	11,648,000	11,477,000	---	12,649,000	12,825,000	ARB
Trips on at-work tours	1,661,000	1,577,000	1,878,000	1,847,000	---	1,998,000	1,982,000	ARB
Trips on non-mandatory tours	11,541,000	11,684,000	11,973,000	12,088,000	---	13,737,000	14,616,000	ARB
Average trip distance	6.5	6.3	6.2	6.3	---	6.2	6.1	ARB
Average auto trip length (miles)	7.1	6.9	6.8	6.9	---	6.8	6.6	ARB; PTS 45
Average walk trip length (miles)	0.9	0.9	0.9	0.9	---	0.9	0.9	ARB; PTS 45
Average bike trip length (miles)	2.4	2.4	2.4	2.4	---	2.4	2.4	ARB; PTS 45
Average transit trip length (miles)	9.2	9.1	9.4	9.8	---	9.7	9.6	ARB; PTS 45
Average trip duration (minutes)	16.3	16.1	16.6	16.6	---	17.4	16.8	ARB
Primary tour duration (minutes)	---	---	---	---	---	---	---	---
Secondary tour duration (minutes)	---	---	---	---	---	---	---	---
MODE SHARE FOR ALL TRIPS								
SOV	49.6%	49.5%	49.2%	49.1%	---	48.9%	47.6%	ARB; PTS 50
HOV (2)	19.2%	19.0%	18.0%	18.0%	---	18.1%	18.1%	ARB; PTS 50
HOV (3+)	14.9%	14.9%	13.9%	13.8%	---	14.0%	13.9%	ARB; PTS 50

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035 (Project)	2040		RTP SCS Chapter-Page(s)
			(Without Project)	(With Project)		(Without Project)	(With Project)	
Public transit (Local bus)	2.6%	2.5%	2.8%	2.9%	---	2.8%	3.1%	ARB
Public transit (Express Bus)	0.2%	0.2%	0.2%	0.5%	---	0.2%	0.5%	ARB
Public transit (Light Rail/Ferry)	0.7%	0.9%	1.4%	1.6%	---	1.4%	1.6%	ARB
Public transit (Heavy Rail)	1.4%	1.4%	1.7%	1.5%	---	1.8%	1.8%	ARB
Public transit (Commuter Rail)	0.1%	0.1%	0.1%	0.3%	---	0.1%	0.3%	ARB
Non-motorized: Bike	1.1%	1.1%	1.3%	1.3%	---	1.3%	1.3%	ARB; PTS 51
Non-motorized: Walk	10.1%	10.3%	11.3%	11.0%	---	11.4%	11.7%	ARB; PTS 51
PERCENT MODE SHARE (peak period)								
SOV	---	---	---	---	---	---	---	---
HOV/HOT	---	---	---	---	---	---	---	---
Local, express bus, and neighborhood shuttle operation	---	---	---	---	---	---	---	---
Public transit (Express Bus)	---	---	---	---	---	---	---	---
Public transit (BRT)	---	---	---	---	---	---	---	---
Public transit (Rail)	---	---	---	---	---	---	---	---
Non-motorized: Bike	---	---	---	---	---	---	---	---
Non-motorized: Walk	---	---	---	---	---	---	---	---
TRANSIT BOARDINGS BY TECHNOLOGY								
Local bus	---	957,000	1,256,000	1,362,000	1,562,000	1,405,000	1,669,000	ARB; PTS 56
Light rail	---	206,000	357,000	404,000	467,000	393,000	504,000	ARB; PTS 56
Heavy rail (BART)	---	342,000	440,000	407,000	494,000	512,000	539,000	ARB; PTS 56
Commuter rail	---	17,000	27,000	67,000	78,000	32,000	84,000	ARB; PTS 56
All technologies (may not sum due to rounding)	---	1,581,000	2,151,000	2,449,000	2,821,000	2,431,000	3,032,000	ARB; PTS 56
AVERAGE DAILY VEHICLE MILES TRAVELED PER BAY AREA RESIDENT BY COUNTY OF RESIDENCE								
San Francisco	---	7.4	7.3	6.8	---	6.8	6.1	ARB
San Mateo	---	16.7	16.1	15.8	---	15.1	14.8	ARB
Santa Clara	---	15.4	16.1	15.2	---	15.5	14.1	ARB
Alameda	---	15.4	14.7	14.9	---	13.8	13.7	ARB

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035 (Project)	2040		RTP SCS Chapter-Page(s)
			(Without Project)	(With Project)		(Without Project)	(With Project)	
Contra Costa	---	18.8	16.6	17.8	---	16.6	16.4	ARB
Solano	---	16.4	16.6	16.7	---	17.0	15.3	ARB
Napa	---	17.6	16.2	16.3	---	16.2	15.2	ARB
Sonoma	---	18.9	17.5	17.4	---	17.7	15.8	ARB
Marin	---	18.5	19.1	19.3	---	18.9	18.4	ARB
All counties	---	15.6	15.0	15.0	---	14.6	13.8	ARB
AVERAGE DAILY VEHICLE MILES TRAVELED PER BAY AREA WORKER BY COUNTY OF WORKPLACE								
San Francisco	---	12.6	---	---	---	10.1	9.8	ARB
San Mateo	---	29.0	---	---	---	25.2	24.1	ARB
Santa Clara	---	24.6	---	---	---	22.0	20.2	ARB
Alameda	---	25.8	---	---	---	23.0	22.7	ARB
Contra Costa	---	27.3	---	---	---	25.6	24.9	ARB
Solano	---	24.3	---	---	---	21.4	21.1	ARB
Napa	---	27.8	---	---	---	27.4	27.3	ARB
Sonoma	---	22.6	---	---	---	21.6	21.0	ARB
Marin	---	34.0	---	---	---	30.9	29.0	ARB
All counties	---	23.8	---	---	---	21.4	20.3	ARB
VEHICLE MILES TRAVELED								
Total 9-county *EMFAC* VMT per typical weekday (all vehicles) (miles)	174,041,000	170,938,000	184,878,000	183,812,000	200,582,000	207,485,000	205,334,000	ARB
Total 9-county EMFAC VMT per typical weekday for passenger vehicles	158,044,000	155,668,000	167,442,000	166,419,000	179,968,000	186,116,000	184,218,000	ARB
Total 9-county *EMFAC* II (Internal) VMT per weekday for passenger vehicles (miles)	138,697,000	---	---	142,423,000	151,437,000	---	---	ARB
Total 9-county *EMFAC* IX/XI VMT per weekday for passenger vehicles (miles)	19,248,000	---	---	24,023,000	28,343,000	---	---	ARB
Total 9-county *EMFAC* XX VMT per weekday for passenger vehicles (miles)	99,000	---	---	162,000	188,000	---	---	ARB

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035 (Project)	2040		RTP SCS Chapter-Page(s)
			(Without Project)	(With Project)		(Without Project)	(With Project)	
CONGESTED TRAVEL MEASURES								
Congested weekday *Assigned* VMT on all roadways (miles, V/C ratios >0.75)	21,744,000	18,388,000	21,776,000	20,920,000	26,168,000	33,372,000	27,937,000	ARB
Congested weekday *Assigned* VMT on all freeways (miles, V/C ratios>0.75)	15,869,000	13,217,000	15,132,000	14,647,000	17,918,000	23,107,000	19,084,000	ARB
Assigned VMT at travel speeds slower than 15 mph	---	278,000	501,000	432,000	654,000	1,464,000	728,000	ARB
Assigned VMT at travel speeds between 15 and 30 mph	---	26,258,000	28,220,000	27,310,000	30,526,000	33,785,000	31,399,000	ARB
Assigned VMT at travel speeds between 30 and 45 mph	---	32,446,000	33,538,000	34,935,000	39,342,000	42,152,000	40,683,000	ARB
Assigned VMT at travel speeds between 45 and 60 mph	---	45,564,000	50,694,000	50,010,000	52,958,000	54,279,000	54,458,000	ARB
Assigned VMT at travel speeds faster than 60 mph	---	32,563,000	34,559,000	34,971,000	37,759,000	33,883,000	37,698,000	ARB
Assigned VMT to constant speed links	---	11,937,000	12,820,000	12,748,000	14,019,000	14,496,000	14,431,000	ARB
Total Assigned VMT	---	149,046,000	160,332,000	160,407,000	175,257,000	180,060,000	179,397,000	ARB; PTS 58
CO2 EMISSIONS[28]								
Total SB 375 CO2 emissions per weekday for passenger vehicles (ARB vehicle classes LDA, LDT1, LDT2, and MDV) (tons) (not including policy initiatives)	71,660	70,090	75,390	74,420	80,630	84,210	82,550	ARB; PTS 64

[28] Please provide ARB staff with the EMFAC Input and Output files associated with these outputs.

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035 (Project)	2040		RTP SCS Chapter-Page(s)
			(Without Project)	(With Project)		(Without Project)	(With Project)	
Total II (Internal) SB 375 CO2 emissions per weekday for passenger vehicles (tons) (not including policy initiatives)	63,020	---	---	66,530	67,800	---	---	ARB
Total IX / XI trip CO2 emissions per weekday for passenger vehicles (tons) (not including policy initiatives)	8,590	---	---	7,840	12,740	---	---	ARB
Total XX trip CO2 emissions per weekday for passenger vehicles (tons) (not including policy initiatives)	50	---	---	50	90	---	---	ARB
INVESTMENT								
Total plan period investment (YOE$, millions)	---	---	---	---	---	---	$292,000	PBA p 66
Highway and bridge capacity expansion (YOE$, millions)	---	---	---	---	---	---	$11,500	
Other Complete Streets capacity expansion (YOE$, millions)	---	---	---	---	---	---	$3,800	
Transit capacity expansion (YOE$, millions)	---	---	---	---	---	---	$21,000	PBA p 66
Bus transit capacity expansion (YOE$, millions)	---	---	---	---	---	---	**included above*	
Transit - maintain and sustain existing infrastructure (YOE$, millions)	---	---	---	---	---	---	$159,000	PBA p 66
Rail transit- maintain and sustain existing infrastructure (YOE$, millions)	---	---	---	---	---	---	**included above*	
Bike and pedestrian projects (YOE$, millions)	---	---	---	---	---	---	**included with Complete Streets capacity expansion and Complete Streets maintain and sustain existing infrastructure*	

Modeling Parameters	2005 (if available)	2010 (base year)	2020		2035 (Project)	2040		RTP SCS Chapter-Page(s)
			(Without Project)	(With Project)		(Without Project)	(With Project)	
Other(Complete Streets – maintain and sustain existing infrastructure) (YOE$, millions)	---	---	---	---	---	---	$93,800	
TRANSPORTATION USER COSTS AND PRICING								
Perceived vehicle operating costs (2009 cents per mile)		$0.23	$0.28	$0.28	$0.28	$0.29	$0.29	PTS 37
Gasoline price (2009$ per gallon)		$3.25	$4.74	$4.74	$5.24	$5.40	$5.40	PTS 37
Parking price ($ per day)	---	---	---	---	---	---	---	PTS 36
Toll price ($ per trip)	---	---	---	---	---	---	---	PTS 29-35
Congestion price ($ per mile)	---	---	---	---	---	---	---	p 85; PTS 38
Average transit fare per passenger mile ($ per mile)	---	---	---	---	---	---	---	

APPENDIX B. 2010 CTC RTP Guidelines Addressed in MTC's RTP/SCS

This Appendix lists the requirements in the California Transportation Commission's (CTC) Regional Transportation Planning (RTP) Guidelines that are applicable to the MTC regional travel demand model, and which MTC followed. In addition, listed below are the recommended practices from the CTC RTP Guidelines that MTC incorporated into its modeling system.

Requirements

- Each MPO shall model a range of alternative scenarios in the RTP Environmental Impact Report based on the policy goals of the MPO and input from the public.
- MPO models shall be capable of estimating future transportation demand at least 20 years into the future. (Title 23 CFR Part 450.322(a))
- For federal conformity purposes, each MPO shall model criteria pollutants from on-road vehicles as applicable. Emission projections shall be performed using modeling software approved by the EPA. (Title 40 CFR Part 93.111(a))
- Each MPO shall quantify the reduction in greenhouse gas emissions projected to be achieved by the SCS. (California Government Code Section 65080(b)(2)(G))
- The MPO, the state(s), and the public transportation operator(s) shall validate data utilized in preparing other existing modal plans for providing input to the regional transportation plan. In updating the RTP, the MPO shall base the update on the latest available estimates and assumptions for population, land use, travel, employment, congestion, and economic activity. The MPO shall approve RTP contents and supporting analyses produced by a transportation plan update. (Title 23 CFR Part 450.322(e))
- The metropolitan transportation plan shall include the projected transportation demand of persons and goods in the metropolitan planning area over the period of the transportation plan. (Title 23 CFR Part 450.322(f)(1))
- The region shall achieve the requirements of the Transportation Conformity Regulations of Title 40 CFR Part 93.
- Network-based travel models shall be validated against observed counts (peak- and off-peak, if possible) for a base year that is not more than 10 years prior to the date of the conformity determination. Model forecasts shall be analyzed for reasonableness and compared to historical trends and other factors, and the results shall be documented. (Title 40 CFR Part 93.122 (b)(1)(i))

- Land use, population, employment, and other network-based travel model assumptions shall be documented and based on the best available information. (Title 40 CFR Part 93.122 (b)(1)(ii))
- Scenarios of land development and use shall be consistent with the future transportation system alternatives for which emissions are being estimated. The distribution of employment and residences for different transportation options shall be reasonable. (Title 40 CFR Part 93.122(b)(1)(iii))
- A capacity-sensitivity assignment methodology shall be used, and emissions estimates shall be based on methodology which differentiates between peak- and off-peak link volumes and speeds and uses speeds based on final assigned volumes. (Title 40 CFR Part 93.122 (b)(1)(iv))
- Zone-to-zone travel impedance used to distribute trips between origin and destination pairs shall be in reasonable agreement with the travel times that are estimated from final assigned traffic volumes. (Title 40 CFR Part 93.122(b)(1)(v))
- Network-based travel models shall be reasonably sensitive to changes in the time(s), cost(s), and other factors affecting travel choices. (Title 40 CFR Part 93.122 (b)(1)(vi))
- Reasonable methods in accordance with good practice shall be used to estimate traffic speeds and delays in a manner that is sensitive to the estimated volume of travel on each roadway segment represented in the network-based travel model. (Title 40 CFR Part 93.122(b)(2))

Recommendations

- During the development period of more sophisticated/detailed models, there may be a need to augment current models with other methods to achieve reasonable levels of sensitivity. Post-processing should be applied to adjust model outputs where the models lack capability, or are insensitive to a particular policy or factor. The most commonly referred to post-processor is a “D’s” post-processor, but post-processors could be developed for other non-D factors and policies, too.
- The models should address changes in regional demographic patterns.
- Measures of means of travel should include percentage share of all trips (work and non-work) made by all single occupant vehicle, multiple occupant vehicle, or carpool, transit, walking, and bicycling.
- To the extent practical, travel demand models should be calibrated using the most recent observed data including household travel diaries, traffic counts, gas receipts, Highway Performance Monitoring System (HPMS), transit surveys, and passenger counts.
- It is recommended that transportation agencies have an on-going model improvement program to focus on increasing model accuracy and policy

sensitivity. This includes on-going data development and acquisition programs to support model calibration and validation activities.

- Agencies are encouraged to participate in the California Inter-Agency Modeling Forum. This venue provides an excellent opportunity to share ideas and help to ensure agencies are informed of current modeling trends and requirements.
- MPOs should work closely with state and federal agencies to secure additional funds to research and implement the new land use and activity-based modeling methodologies. Additional research and development is required to bring these new modeling approaches into mainstream modeling practice.
- The travel model set should be run to a reasonable convergence towards equilibrium across all model steps.
- A simple freight model should be developed and used.
- Several employment types should be used, along with several trip purposes.
- The models should have sufficient temporal resolution to adequately model peak and off-peak periods.
- Agencies should, at a minimum, have four-step models with full feedback across travel model steps and some sort of land use modeling.
- In addition to the conformity requirements, these regions should also add an auto ownership step and make this step and the mode choice equations for transit, walking and bicycling and the trip generation step sensitive to land use variables and transit accessibility.
- Small Traffic Analysis Zones (TAZ) should be used, to increase sensitivity to infill potential near to rail stations and in Bus Rapid Transit (BRT) corridors. Parking quantity and cost should be represented in the travel model.
- The carpool mode should be included, along with access-to-transit sub modes.
- Feedback loops should be used and take into account the effects of corridor capacity, congestion and bottlenecks on mode choice, induced demand, induced growth, travel speed and emissions.
- Freight models should be implemented in the short term and commodity flows models within a few years.
- Simple Environmental Justice analyses should be done using travel costs or mode choice log sums, as in Group C. Examples of such analyses include the effects of transportation and development scenarios on low-income or transit-dependent households, the combined housing/transportation cost burden on these households, and the jobs/housing fit.

- Household travel surveys should be activity-based and include a tour table. GPS sampling is encouraged or extra emphasis should be placed on accurate geocoding of households, workplace locations, and stops. Regions should take care in the design and data collection procedures of the survey to ensure survey results are appropriate to the type of model being utilized. Coordination with Caltrans' travel survey efforts is encouraged.

APPENDIX C. Changes Made to Draft Plan Bay Area that Could Affect Greenhouse Gas Quantification

This appendix lists key changes that ABAG/MTC made to the Draft Plan Bay Area, in the creation of the Final Plan Bay Area. ARB staff considered these changes in their review of ABAG/MTC's GHG quantification.

- The draft Plan Bay Area indicated that 80 percent of new housing and 66 percent of new jobs would be located in PDAs. The final Plan Bay Area shows 78 percent of new housing and 62 percent of new jobs in PDAs. ABAG/MTC staff reported that, while the overall percentages of new housing and jobs located in areas designated as PDAs were reduced, the actual numbers of new housing and jobs in those same locations are not expected to be reduced; rather, the change reflects a revision in the removal of the PDA designation in certain locations. Therefore, these changes are not expected to affect ABAG/MTC's GHG quantification.

- Several cities requested changes to their PDAs after ABAG/MTC adopted the Jobs-Housing Connection Strategy and after the development of the Plan Bay Area Draft Environmental Impact Report had begun. ABAG and MTC incorporated these changes into the PDA data set. The nature of the requested changes includes reclassifying some PDAs as "Potential PDAs" and others as "Planned PDAs." A "Planned PDA" has a formally adopted plan, as determined by a local jurisdiction. A "Potential PDA" requires more local planning, review and action before it can become a Planned PDA. These changes are not expected to affect ABAG/MTC's GHG quantification.

- Changes were made to discretionary funding, by adding about $2 billion more for building new transit, and about $1 billion more for reserves as a result of assuming about $3 billion over the life of the plan will be available from Cap and Trade funding. As ABAG/MTC has not yet determined the uses of the expected Cap and Trade funding, the effect of this change to Plan Bay Area on ABAG/MTC's GHG quantification is not known. However, ABAG/MTC plans to use these funds for such projects as transit operating and capital rehabilitation or replacement, local street and road rehabilitation, goods movement, and transit-oriented affordable housing.

- Car Sharing per capita CO_2 emissions reductions in 2035 changed from -2.8 percent to -2.6 percent. Smart Driving per capita CO_2 emissions reductions in 2020 changed from -1.9 percent to -1.8 percent, and in 2035 changed from -1.6 percent to -1.5 percent. These changes result in total Climate Initiatives

program reductions in 2020 of -5.0 percent instead of the draft -5.1 percent, and in 2035 of -6.3 percent instead of draft -6.6 percent.