PLAN BAY AREA 2050

FORECASTING AND MODELING REPORT

OCTOBER 2021

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ACKNOWLEDGEMENTS

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Executive Summary

This report presents a technical overview of the forecasting and modeling processes performed in support of the Association of Bay Area Governments (ABAG) and the Metropolitan Transportation Commission's (MTC) Plan Bay Area 2050. The plan included several phases of modeling and analysis (described in detail in Chapter 1. This report focuses primarily on the later phases of the planning process, the Final Blueprint and Environmental Impact Report (EIR) analyses, as these phases built upon and refined work from prior phases like Horizon and the Draft Blueprint. The report includes details on each of the modeling components that are used to analyze the plan strategies.

The first step in the modeling process is the development of the **Regional Growth Forecast**, which uses the Regional Economic Models, Inc. (REMI) Policy Insight+ (or PI+) tool to forecast the growth in jobs by industry, housing units and population in the Bay Area. Custom inputs and adjustments to the model are described in detail in Chapter 2, as well as the post processes which derive household size and income distributions from this high-level Regional Growth Forecast. The second step in the modeling process is the application of the **Land Use Model**, which is used to forecast that regional growth in jobs and households at more specific geographies — jurisdictions and travel analysis zones — within the Bay Area. MTC and ABAG use Bay Area UrbanSim 2 (BAUS2) for this analysis, which is a custom variant of the UrbanSim model with additional features developed for policy priorities in the Bay Area. The third step in the modeling process is the application of the **Travel Model**, which simulates the travel of each forecasted Bay Area resident on an average weekday in a given model year as they travel to their workplace and other destinations using the planned transportation infrastructure. The travel modeling process includes a forecast of travel by different modes of transportation and analysis of greenhouse gas emissions generated from the vehicle miles traveled.

There are two additional data exchanges between these modeling components (described in more detail in the **Model System Overview**). First, staff incorporates feedback from the Land Use Model analysis into the Regional Growth Forecast to capture the effects of strategies that affect housing supply and prices as well as job locations and type; this feedback is new to the process and was not included in previous long-range plans. Second, staff incorporates feedback from the Travel Model analysis into the Land Use Model by feeding back measures of accessibility from the travel model into BAUS2. This means that transportation strategies, as well as overall traffic congestion, affecting accessibility can affect the value of commercial and residential development.

For each of these modeling tools, the respective section in the report describes the modeling methodology, including input assumptions inherent to all scenarios. Each section then includes details about how the strategies that comprise the Plan and the EIR Alternatives are represented in the modeling process. Finally, each section describes some high-level findings.

Between 2015 and 2050, the region's employment is projected to grow by 1.4 million to just over 5.4 million total jobs. Population is forecasted to grow by 2.7 million people to 10.3 million. This population will comprise over 4.0 million households, for an increase of nearly 1.4 million households from 2015. At a more local level, the Plan focuses that growth in both Transit-Rich Areas and High-Resource Areas while improving the jobs-housing balance in the region's most populous counties. The Plan also improves non-automobile mode shares, with substantial increases in transit boardings, while reducing vehicle miles traveled and greenhouse gas emissions per capita.

Plan Bay Area 2050 modeling analysis was performed in several phases. As part of the **Horizon Initiative's Futures Planning**,[1] staff developed and studied three divergent what-if scenarios called "Futures" to identify how a range of forces could potentially shape the Bay Area. Futures Planning transcended previous scenario planning efforts by including a greater variety of political, technological, economic, and environmental challenges that will impact Bay Area residents.

Using the futures defined and modeled during Futures Planning, staff conducted the **Project Performance Assessment**[2] to understand how major transportation investments would fare in an uncertain future. By modeling major transportation projects and strategies within the context of the divergent futures, the Project Performance Assessment explored synergies between individual projects and strategies More information on the Project Performance Assessment process can be found in the Plan Bay Area 2050 Performance Report.

Before embarking on the core modeling effort of Plan Bay Area 2050, one further phase of modeling was performed: the **Incremental Progress Assessment**. Requested by the California Air Resources Board[3], the Incremental Progress Assessment enables "a normalized comparison, to the greatest degree feasible, of the previously submitted RTP/SCS [Regional Transportation Plan/Sustainable Communities Strategy] to the proposed RTP/SCS". This involved applying current exogenous variables and the updated modeling framework to the previous plan inputs – in this case, using the land use distribution and transportation networks from Plan Bay Area 2040. This assessment served to show the size of the region's greenhouse gas emissions reduction gap with respect to regional targets.

Building upon the earlier steps, the modeling team began the technical analysis for the plan, and the first step was the development of the **Regional Growth Forecast**. That is, before developing a localized growth pattern as part of the plan, a long-range regional growth forecast must be developed to identify the number of people, jobs and housing units required through 2050. The findings from this analysis — that the Bay Area must accommodate 1.5 million new homes (necessary to house the anticipated expanded population and address overcrowding) and 1.4 million new jobs — underpinned the remaining phases of modeling.

Informed by the results of the Horizon Initiative's Futures Planning and the Project Performance Assessment, 25 transportation, housing, economic and environmental strategies, alongside an expanded set of Growth Geographies, were developed and analyzed in the **Draft Blueprint**. After feedback from stakeholders and the public following findings from the Draft Blueprint analysis, these strategies were then refined and expanded into a set of 35 Plan strategies through the Final Blueprint phase. Throughout the Plan Bay Area 2050 process, a strategy is defined as a public policy or set of investments that can be implemented in the Bay Area at the city, county, regional or state level over the next 30 years. The Blueprint integrated critical strategies to address regional challenges, such as the Bay Area's severe and longstanding housing crisis. With infrastructure investments in walking, biking and public transportation — as well as critical sea level protections designed to keep most Bay Area communities from flooding through 2050 — the Blueprint made meaningful progress toward the adopted Plan Bay Area 2050 vision and advanced critical climate and equity goals. Additionally, three additional alternatives were developed for analysis in the Environmental Impact Report: the **EIR Alternatives** (including the No Project Alternative).

In the sections that follow, input assumptions and methodology primarily refer to the modeling done for the Final Blueprint, hereby referred to as the **Plan** and **EIR Alternatives**.

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1 See more information about Horizon and Futures Planning: https://www.planbayarea.org/2050-plan/horizon.

2 See more information about the Horizon/Plan Bay Area 2050 Project Performance Assessment: https://mtc.ca.gov/our-work/plans-projects/horizon/project-performance-assessment.

3 See CARB's Final Sustainable Communities Strategy Program and Evaluation Guidelines: https://ww2.arb.ca.gov/sites/default/files/2019-11/Final%20SCS%20Program%20and%20Evaluation%20Guidelines%20Report.pdf.

Consistency with the Regional Housing Needs Allocation

Plan Bay Area 2050 identifies Growth Geographies and strategies for the next 30 years, whereas the Regional Housing Needs Allocation is a short-to-medium term housing allocation process, distributing growth as assigned by California Housing and Community Development. While each process is subject to a different set of objectives established by state and/or federal law, Plan Bay Area 2050 contains a range of strategies that would bolster housing production and increase zoned capacity in identified Growth Geographies. The estimated impact of the full bundle of strategies is that by 2050, the region would have an additional 1.4 million households and 1.5 million housing units (see Table 8), well above the 441,000 housing-unit need identified for the 8-year period from 2023-2031. Given that Plan Bay Area 2050 accommodates more than three times the number of new housing units required in the next eight years, staff can confirm that Plan Bay Area 2050 identifies areas within the region "sufficient to house an eight-year projection of the regional housing need for the region."

Model System Overview

Analysis for Plan Bay Area 2050 involves a sequence of modeling tools used together to create and study the scenarios of interest. The Regional Growth Forecast is the first step, identifying how much the Bay Area might grow between the plan baseline year (2015) and the plan horizon year (2050), including population, jobs, households, and associated housing units. The location of these households and jobs are then projected on a more localized level throughout the Bay Area by the Land Use Model (Bay Area UrbanSim 2, hereby referred to as BAUS2), which represents the potential effects of land use strategies and infrastructure investments. These first two models each represent the entire sequence of years in five-year increments, starting with the plan baseline year and ending at the plan horizon year. Finally, the Travel Model is used to analyze an average weekday for a single given model year, simulating a day's worth of travel for each Bay Area resident given their daily activities and enabling staff to understand the effects of transportation strategies on daily vehicle miles traveled, transit ridership and active transportation.

The strategies that comprise the Plan and the EIR Alternatives are listed below, along with the modeling tools used to quantify them. The column with the heading "Off-Model" refers to analysis done to quantify the effects of these strategies outside of the other modeling tools. More detail the off-model processes used to estimate greenhouse gas emissions can be found in the section Off-Model Calculations. Some strategies were represented consistently across the Plan and EIR Alternatives 1 and 2; these are noted as "Included in all EIR Alternatives except No Project." Some strategies are included in the different alternatives with different details depending on the alternative; these are noted as "Variants included in all EIR Alternatives (except No Project)." Further information about how the strategies are represented in the modeling tools can be found in the Strategy Implementation section within the larger section on that modeling tool.

Table 1. Strategy modeling tools

STRATEGY	EIR ALTERNATIVES	REMI	BAUS2	TM1.5	OFF-MODEL
Housing | Protect and Preserve Affordable Housing					
H1: Further Strengthen Renter Protections Beyond State Law	Included in all EIR Alternatives except No Project	-	✓	-	-
H2: Preserve Existing Affordable Housing	Variants included in all EIR Alternatives	✓	✓	-	-
Housing | Spur Housing Production for Residents of All Income Levels					
H3: Allow a Greater Mix of Housing Densities and Types in Growth Geographies	Variants included in all EIR Alternatives except No Project	✓	✓	-	-
H4: Build Adequate Affordable Housing to Ensure Homes for All	Variants included in all EIR Alternatives	✓	✓	-	-
H5: Integrate Affordable Housing into All Major Housing Projects	Included in all EIR Alternatives except No Project	✓	✓	-	-
H6: Transform Aging Malls and Office Parks into Neighborhoods	Variants included in all EIR Alternatives except No Project	✓	✓	-	-
Housing | Create Inclusive Communities					
H7: Provide Targeted Mortgage, Rental and Small Business Assistance to Equity Priority Communities	Variants included in all EIR Alternatives except No Project	-	-	-	✓
H8: Accelerate Reuse of Public and Community Land for Mixed-Income Housing and Essential Services	Variants included in all EIR Alternatives except No Project	✓	✓	-	-

STRATEGY	EIR ALTERNATIVES	REMI	BAUS2	TM1.5	OFF-MODEL
Economy | Improve Economic Mobility					
EC1: Implement a Statewide Universal Basic Income	Included in all EIR Alternatives except No Project	✓	-	-	✓
EC2: Expand Job Training and Incubator Programs	Included in all EIR Alternatives except No Project	✓	✓	-	-
EC3: Invest in High-Speed Internet in Underserved Low-Income Communities	Not modeled	-	-	-	-
Economy | Shift the Location of Jobs					
EC4: Allow Greater Commercial Densities in Growth Geographies	Variants included in all EIR Alternatives except No Project	-	✓	-	-
EC5: Provide Incentives to Employers to Shift Jobs to Housing-Rich Areas Well Served by Transit	Included in all EIR Alternatives except No Project	-	✓	-	-
EC6: Retain and Invest in Key Industrial Lands	Included in all EIR Alternatives except No Project	-	✓	-	-
EC7: Assess Transportation Impact Fees on New Office Developments	Included in EIR Alternative 1 only	-	✓	-	-
EC8: Implement Office Development Caps in Job-Rich Cities	Included in EIR Alternative 2 only	-	✓	-	-

STRATEGY	EIR ALTERNATIVES	REMI	BAUS2	TM1.5	OFF-MODEL
Transportation | Maintain and Optimize the Existing System					
T1: Restore, Operate and Maintain the Existing System	Variants included in all EIR Alternatives	✓	-	✓	-
T2: Support Community-Led Transportation Enhancements in Equity Priority Communities	Not modeled	-	-	-	-
T3: Enable a Seamless Mobility Experience	Included in all EIR Alternatives except No Project	-	-	✓	-
T4: Reform Regional Transit Fare Policy	Variants included in all EIR Alternatives except No Project	✓	-	✓	-
T5: Implement Per-Mile Tolling on Congested Freeways with Transit Alternatives	Included in all EIR Alternatives except No Project	✓	-	✓	-
T6: Improve Interchanges and Address Highway Bottlenecks	Variants included in all EIR Alternatives	✓	-	✓	-
T7: Advance Other Regional Programs and Local Priorities	Variants included in all EIR Alternatives	✓	-	✓	-
Transportation | Create Healthy and Safe Streets					
T8: Build a Complete Streets Network	Included in all EIR Alternatives except No Project	✓	-	✓	-
T9: Advance Regional Vision Zero Policy through Street Design and Reduced Speeds	Included in all EIR Alternatives except No Project	-	-	✓	-
Transportation | Build a Next-Generation Transit Network					
T10: Enhance Local Transit Frequency, Capacity and Reliability	Variants included in all EIR Alternatives	✓	-	✓	-
T11: Expand and Modernize the Regional Rail Network	Variants included in all EIR Alternatives	✓	-	✓	-
T12: Build an Integrated Regional Express Lanes and Express Bus Network	Variants included in all EIR Alternatives	✓	-	✓	-

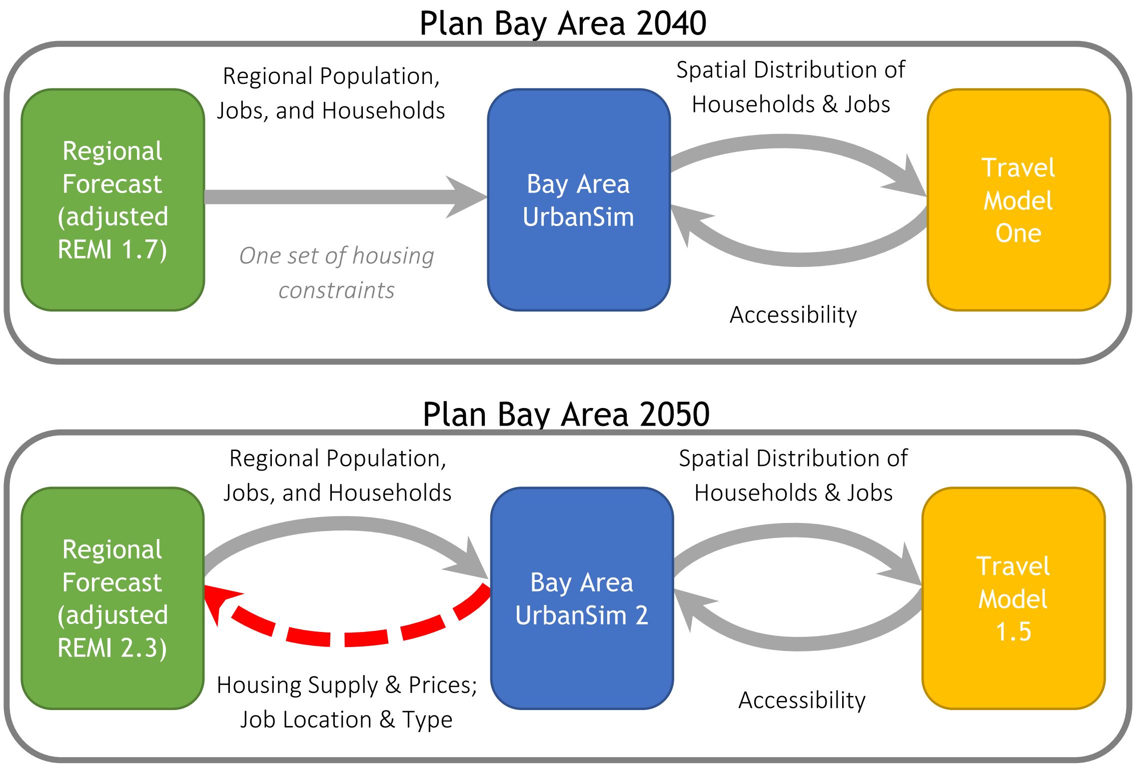
STRATEGY	EIR ALTERNATIVES	REMI	BAUS2	TM1.5	OFF-MODEL
Environment | Reduce Risks from Hazards					
EN1: Adapt to Sea Level Rise	Variants included in all EIR Alternatives	✓	✓	✓	-
EN2: Provide Means-Based Financial Support to Retrofit Existing Residential Buildings	Included in all EIR Alternatives except No Project	✓	-	-	✓
EN3: Fund Energy Upgrades to Enable Carbon-Neutrality in All Existing Commercial and Public Buildings	Included in all EIR Alternatives except No Project	-	-	-	✓
Environment | Expand Access to Parks and Open Space					
EN4: Maintain Urban Growth Boundaries	Variants included in all EIR Alternatives except No Project	-	✓		-
EN5: Protect and Manage High-Value Conservation Lands	Not modeled	-	-	-	✓
EN6: Modernize and Expand Parks, Trails and Recreation Facilities	Not modeled	-	-	-	✓
Environment | Reduce Climate Emissions					
EN7: Expand Commute Trip Reduction Programs at Major Employers	Included in all EIR Alternatives except No Project	-	✓	✓	-
EN8: Expand Clean Vehicle Initiatives	Included in all EIR Alternatives except No Project	-	-	-	✓
EN9: Expand Transportation Demand Management Initiatives	Included in all EIR Alternatives except No Project	-	-	✓	✓

Although these models are run in sequence, they are run multiple times and iteratively so that they interact with each other, and metrics produced by downstream models can factor into upstream models. For example, transportation strategies that affect travel accessibilities will affect land use outcomes because of the feedback from the Travel Model to Bay Area UrbanSim 2.

Regional Growth Forecast and Land Use Model Interaction

The Regional Growth Forecast, produced by MTC and ABAG staff using the Regional Economic Models, Inc. (REMI) demographic and economic model, and the land use model interact with each other in two ways. In previous plans, the Regional Growth Forecast identified the total amount of population, job, household, and housing unit growth, which was then forecast to grow in local areas using the Bay Area UrbanSim land use model based on strategies integrated into the plan.

Figure 1. Integrated model flow Plan Bay Area 2040 vs. Plan Bay Area 2050



The Bay Area's housing market is so far from equilibrium[4] that strategies to increase housing supply at all income levels (thereby lowering housing prices) would affect the location of firms, labor markets, households, housing markets, and city size.[5] Additionally, a housing market that is closer to equilibrium would be able to accommodate those priced out of the region into the megaregion and beyond, reducing in-commute need. To better capture the impact of changed local housing policies on regional housing prices and the overall regional growth trajectory, staff added a feedback link to the model flow, which would enable a more complete analysis of housing price outcomes. The new approach was informally referred to as the "Backward Arrow" during the Plan Bay Area 2050 process, shown in red in Figure 1 above.

To implement this feedback linkage, housing strategies were tested in Bay Area UrbanSim 2 to find a package to allow for the construction of sufficient low-income deed-restricted units and market-rate units by 2050 to drive down the housing cost to year 2000 levels. On the regional model side, staff worked within limitations of the REMI model; since it does not explicitly treat the count of housing units, the key lever used to represent the increase in housing supply was to adjust the model's representation of the region's housing prices relative to the nation. Therefore, staff adjusted the relative housing price and investment variables accordingly in REMI. Additionally, adjustments to headship rates and vacancy rates were made to reflect a healthier and more dynamic housing market to estimate household and housing unit numbers. These processes are discussed later in detail.

4 For further explanation, please see Edward Glaeser and Joseph Gyourko. "The Economic Implications of Housing Supply" NBER Working Paper No. 23833, September 2017.

5 For further explanation, please see Chang-Tai Hsieh and Enrico Moretti. "Housing Constraints and Spatial Misallocation" American Economic Journal: Macroeconomics. 2019, 11(2): 1–39.

Land Use Model and Travel Model Interaction

Bay Area UrbanSim 2 and Travel Model 1.5 work as a system to capture the interaction between transportation and land use. Accessibility to a variety of destinations and amenities is a key driver in both household and business location choice. For instance, households often prefer locations near employment, retail, and similar households but avoid other features such as industrial land use. Business preferences vary by sector with some firms looking for locations popular with similar firms (e.g., Silicon Valley) while others desire locations near an airport or university. In all cases, the accessibility between a given location in the region (defined as a transportation analysis zone or TAZ) and all other locations/TAZs is provided to BAUS2 by the Travel Model. This data represents overall regional accessibility for future years considering changing infrastructure and policy.

Moving in the other direction, BAUS2 provides the travel model with a projected land use pattern and spatial distribution of activities for each year into the future. This pattern includes the location of housing, jobs, and other activities that serve as the start and end locations for trips predicted by the travel model. This information is provided to the travel model at a TAZ level aggregation for each future year examined. Overall, the linkages between the two models allow land use patterns to evolve in relation to changes in the transportation system and for future travel patterns to reflect dynamic shifts in land use, thus representing long-term induced demand.

Forecast Modeling Suite

The Plan Bay Area 2050 Regional Growth Forecast identifies how much the Bay Area might grow between the plan baseline year (2015) and the plan horizon year (2050), including population, jobs, households, and associated housing units. The forecast also includes important components of that growth, including employment by sector, population by age and ethnic characteristics, and households by income level. These figures were then integrated into the Bay Area UrbanSim 2 land use model which explores how Plan strategies affect growth in households and employment at a local level.

The Plan Bay Area 2050 Regional Growth Forecast was primarily developed using the REMI (Regional Economic Models, Inc.) Policy Insight+ (or PI+) model version 2.3.1[6]; for the remainder of this report, REMI PI+ will be used interchangeably with REMI. The REMI PI+ model integrates into one package a dynamic accounting of the core components of the economy: industry structure and competitiveness relative to other regions, propensity to export, and population and labor market structure. The population is explicitly connected to industry growth and demand for labor, assuming that employment growth is a driving force of regional population and household growth, with migration increasing in times of strong employment growth. This is an updated version of the REMI PI+ model used to calculate the growth forecast for Plan Bay Area 2040, which used REMI PI+ version 1.7.8.

The model produces projections of population, employment, gross regional product, and labor force. To generate other key components of the Regional Growth Forecast, staff also developed a household model and a household income distribution model, built around the projections from the REMI analysis. Household projections are generated through a headship rate analysis. The household module uses the projected age and ethnic distribution of the adult population and a moving average of the percent in different age categories that are heads of household to project the number of households associated with demographic characteristics and size of the population.

The household income distribution analysis estimates the share of households in each of four mutually exclusive income groups, to coincide with analysis required in the transportation model. The share of households in low-, moderate-low-, moderate-high-, and high-income categories is estimated using a regression analysis which ties the share in each wage category with ethnic and age distribution, industry characteristics, relative housing prices, and per capita income.

Modeling Context

For decades, developing a Regional Growth Forecast has been a key element of the long-range transportation planning process for the Bay Area. However, in recent years, it has become apparent that critical issues need to be better addressed in the context of developing such a forecast.

The first is related to regional affordability. In Plan Bay Area 2040, it was estimated that the average share of lower-income household income spent on housing would rise by approximately 13 percentage points; this was due in part to the fact that regional housing strategies were limited in nature and affected only the geographic distribution of forecasted growth rather than overall level of housing growth in the Regional Growth Forecast itself. As part of this planning process, policymakers specifically asked “what it would take” to move the needle on affordability, but solutions for these affordability shortcomings were not identified in time for integration into that plan. Plan Bay Area 2050 presents an opportunity to integrate new housing strategies specifically designed to increase supply for all income levels — consistent with policymaker direction for Plan Bay Area 2050 — which will in turn contribute to a more affordable region and a slightly higher Regional Growth Forecast.

6 REMI PI+: https://www.remi.com/model/pi/.

The second is related to uncertainty. While required by statute, the creation of a single Regional Growth Forecast in prior cycles did not provide the opportunity to explore how different trajectories for regional growth would affect critical environmental, economic, and other goals. To address this gap, MTC and ABAG staff undertook the Horizon Initiative in 2018 and 2019, which explored not only how different growth trajectories would affect the region but also how the region could respond to those different trajectories through new strategies.

Both factors mean that developing the Regional Growth Forecast is a more policy-conscious effort, equally focused on contextual uncertainties as well as policy linkages and implications. Upon the kickoff of the Plan Bay Area 2050 cycle, staff accordingly worked with a technical advisory committee to make methodological refinements that incorporate lessons learned from both efforts. The methodology adopted by the ABAG Executive Board in September 2019 enables the Regional Growth Forecast to incorporate changes in strategies that would affect the level of growth in the region, while also affecting affordability, equity, economic mobility, and other critical outcomes.

MTC and ABAG staff developed a draft range for the Regional Growth Forecast forecasts based on the adopted methodology and sought feedback from technical stakeholders during winter 2020. The Final Regional Growth Forecast incorporates comments and feedback received; it also integrates the effects of key Plan strategies.

With the declaration of a public health emergency by the federal government on January 31, 2020, and shelter-in-place guidelines issued at the state- and countywide levels beginning in March 2020, it became clear that the virus would have a widespread impact on many facets of life, especially over the next one to ten years. The economic impact was recognized in February and March with stock markets declining and unemployment ticking upwards. Therefore, MTC and ABAG staff revised the forecast in April and May 2020, making changes to the employment numbers between 2020 and 2030 to reflect significant economic impacts from the coronavirus pandemic and the 2020 recession over the first ten years of the planning horizon; more details are provided below, in the section, Integrating COVID-19 Pandemic and Subsequent Recession. The revised Final Regional Growth Forecast was adopted in September 2020 with the approval of MTC Resolution No. 4437 and ABAG Resolution No. 16-2020.

REMI Modeling

The following sections first introduce the economic and demographic assumptions that underpin the Final Regional Growth Forecast, as well as adjustments made to the near-term forecast to integrate the impact of the recession spurred by the COVID-19 pandemic. This results in a "status quo" baseline forecast for the future of the Bay Area that reflects near-term economic impacts but does not fully accommodate regional growth in an affordable and equitable manner. The report then delves into how a selection of key strategies from the Plan were incorporated into the Final Regional Growth Forecast to meet the Plan's affordability goals.

Adjustments to REMI Baseline

Demographic Adjustments

Staff adjusted Hispanic international migration based on numbers from the most recent U.S. Census Bureau projections. Compared to Census projections, REMI PI+ 2.3.1 using default inputs (REMI Default) projects 42,000 more Hispanic international migrants in 2020. The difference decreases for the next 30 years, and by 2050, the REMI Default projection is just 1,000 higher than the Census (See Table 2).

Table 2. Hispanic international migration - Census vs REMI PI+ 2.3 default

	2020	2030	2040	2050
Census Hispanic	414,000	412,000	410,000	391,000
REMI Unadjusted Hispanic	456,000	431,000	415,000	392,000
Census Total	1,010,000	1,064,000	1,098,000	1,110,000
REMI Unadjusted Total	1,111,000	1,112,000	1,113,000	1,113,000

SOURCE: REMI PI+ 2.3.1; Census 2017 National Population Projections

Therefore, staff updated REMI's Hispanic international migration assumptions using Census 2020, 2030, and 2040 numbers and interpolated for the in-between years, as the Census trends more closely align with observed data in recent years. The gender and age distributions from REMI were used to produce detailed Hispanic international migration for all years between 2020 and 2050. Additionally, in conversation with the California Department of Finance (DOF) about REMI birth rates, DOF noted that REMI fertility rates are projected to be slightly higher, notably for Hispanic individuals (which could overstate births). REMI Default birth rates are higher than DOF estimates, although somewhat lower than rates found in earlier REMI versions. As a result, staff also reduced Hispanic birth rates at the national level by 20%, consistent with observations from a variety of sources that indicated slowing Hispanic birth rates throughout the country as well as in Mexico. This adjustment lowers the total national population in 2050 by less than 0.3%.

Economic Adjustments

At the national level, staff adjusted the employment growth downward for the data processing sector. Data processing (which includes data processing, hosting, and related services) is projected to grow by 136% between 2018 and 2050 in REMI Default for the nation. REMI Default projects the average annual growth rate for this sector for 2018-2028 to be 2.2%, slightly above the BLS 2018-2028 forecast (2.1%). However, after 2030, REMI Default projects an average annual growth rate of roughly 3% for the data processing sector. Staff adjusted data processing employment using the 2020-2030 annual average growth rate from REMI and assuming a constant growth rate after 2030, which lowers the national total employment slightly.

The REMI Default forecast estimates that the region's share of the U.S. employment and population will continue to grow. The share of U.S. data processing jobs was estimated to grow from 18.5% to 22.5% in 2050. However, this contrasts sharply with historic experience. Based on Bureau of Economic Analysis (BEA) data, the Bay Area's share of total U.S. employment, even at peak periods, has never been above 2.9% and has not reached that level since the early 1990s. Staff identified sector shares to adjust and their period of adjustment, and created new regional controls that keep the share of some sectors constant after 2025 and after 2040, as shown in Table 3.

Table 3. Sector share adjustments made to REMI

1. Sectors with share constant after 2025 (basic sectors):
   - Oil and gas extraction
   - Mining (except oil and gas)
   - Support activities for mining
   - Beverage and tobacco product manufacturing
   - Wholesale trade
   - Data processing, hosting, and related services; Other information services
   - Broadcasting, except Internet
   - Telecommunications
   - Professional, scientific, and technical services
   - Management of companies and enterprises
   - Administrative and support services
2. Sectors with share constant after 2040 (local serving):
   - Construction
   - Retail trade
   - Transit and ground passenger transportation
   - Monetary authorities - central bank; Credit intermediation and related activities
   - Securities, commodity contracts, other investments; Funds, trusts, other financial vehicles

SOURCE: ABAG, MTC, and Center for Continuing Study of the California Economy

Relative Housing Price Adjustment

In REMI, the relative housing price influences overall population levels because it factors into the relative wage levels of the region, net of housing costs. Higher relative prices will make the region less attractive to new workers and labor costs more expensive, all other things equal. REMI does not account for absolute levels for current and future prices but instead provides a measure of relative prices for regions compared to national levels. Staff looked at U.S. Census Bureau American Community Survey (ACS) median home prices and Zillow reported home and rental prices to determine if the REMI relative housing price index had accurately reflected the relative strength of the Bay Area housing market. Based on a review of ACS and Zillow data, staff determined that the price difference was not fully captured in the REMI index. REMI Default shows Bay Area prices ranging from 1.3 times the national level in Solano to 3.6 times the national level in San Francisco in 2018 – with a weighted average of 2.8. Using Zillow homeowner and renter indices, the weighted average of this aggregated series is 3.1, 11% above the REMI price index. Staff used this higher ratio for 2018 for each county and maintained this proportional higher price through 2050. This relative housing price was utilized for adjusting the REMI Default.

Table 4. Relative housing price comparisons - REMI, ACS, and Zillow*

	ACS RELATIVE HOME VALUE	ZILLOW ALL HOME INDEX	ZILLOW RENTAL INDEX	ZILLOW AVERAGE ALL HOME AND RENTAL	REMI	ZILLOW RELATIVE TO REMI
Alameda	4.4	3.6	1.9	2.7	2.5	1.1
Contra Costa	3.5	2.5	1.7	2.1	2.1	1.0
Marin	5.5	4.4	2.4	3.4	3.3	1.0
Napa	3.4	3.3	1.8	2.6	2.0	1.3
San Francisco	6.2	7.0	2.7	4.9	3.6	1.4
San Mateo	6.2	5.9	2.3	4.1	3.5	1.2
Santa Clara	5.7	4.7	2.1	3.4	3.1	1.1
Solano	2.3	1.8	1.3	1.5	1.3	1.2
Sonoma	3.4	2.9	1.7	2.3	2.0	1.2
Weighted Average	**4.8**	**4.0**	**2.2**	**3.1**	**2.8**	**1.1**

SOURCE: ABAG and MTC from REMI PI+ 2.3.1, calculations from data from the American Community Survey, and Zillow Home Value Index (2018, Bay Area Counties and U.S.), Zillow Rental Index (2018, Bay Area Counties and U.S.). Weighted average calculated using California Department of Finance housing unit numbers.

***NOTE:** Staff used Zillow index only because it includes detailed rental information. ACS data was shown for reference in this table.

Integrating COVID-19 Pandemic and Subsequent Recession

While there was limited data at the time of the forecast revision, staff used the available information and consulted with, or reviewed, the work of other forecasters, including but not limited to estimates from the Congressional Budget Office, the UCLA Anderson Forecast (March 16th 2020 report), and the University of Michigan Research Seminar in Quantitative Economics (RSQE) forecast report (March 2020 release). Staff determined that while employment totals would be impacted significantly in the near term, the direct impact on population and households would be more limited as COVID-19 impacts are both nationwide and global.

To represent the near-term economic impacts of the recession caused by the pandemic along with the anticipated subsequent recovery, staff made changes to employment projections in the Plan Bay Area 2050 Final Growth Forecast for the years between 2020 and 2030 in REMI. The regional forecast is meant to represent a moderate growth trend over a thirty-year period and does not typically represent economic cycles. Even recognizing the unprecedented stimulus measures that have been put into place, the recovery from this event is likely to go on for several years. Over the longer term, the Bay Area is expected to return to the previously forecasted trend line by 2030.

Strategy Implementation

The Plan integrated critical strategies to address regional challenges, including the region's longstanding affordability crisis. These strategies would have implications for the level of growth in the region. For example, making the region more affordable would attract more residents who may have otherwise been priced out of the Bay Area. Similarly, the investment associated with building more housing would create more jobs and labor demand. Recognizing these dynamics, based off the baseline forecast, staff sought to incorporate the impacts of the strategies adopted for the Final Blueprint into the Regional Growth Forecast. These strategies impact all the models used, but in this section, the focus is on the REMI PI+ model. Ultimately, not every strategy is anticipated to have significant impacts on the Regional Growth Forecast; many strategies only need to be incorporated in BAUS2 and/or Travel Model 1.5. After reviewing the 35 strategies, staff determined that the following strategies would likely influence the Regional Growth Forecast, with impacts ranging widely across strategies (Table 5).

Table 5. Strategies incorporated in Final Regional Growth Forecast

CATEGORY	STRATEGY	MODEL INPUT ADJUSTMENTS
TRANSPORTATION	Restore, Operate and Maintain the Existing System	Increase investment in construction sector and government administrative spending
	Improve Interchanges and Address Highway Bottlenecks	
	Advance Other Regional Programs and Local Priorities	
	Build a Complete Streets Network	
	Enhance Local Transit Frequency, Capacity and Reliability	
	Expand and Modernize the Regional Rail Network	
	Build an Integrated Regional Express Lanes and Express Bus Network	
	Reform Regional Transit Fare Policy	Increase disposable income (consumer spending)
	Implement Per-Mile Tolling on Congested Freeways with Transit Alternatives	Decrease disposable income
HOUSING	Allow a Greater Mix of Housing Densities and Types in Growth Geographies	Decrease housing costs, increase investment in construction sector
	Accelerate Reuse of Public and Community Land for Mixed-Income Housing and Essential Services	
	Transform Aging Malls and Office Parks into Neighborhoods	
	Preserve Existing Affordable Housing	Increase disposable income (consumer spending) and government administrative spending
	Build Adequate Affordable Housing to Ensure Homes for All	
	Integrate Affordable Housing Into All Major Housing Projects	
ECONOMY	Implement a Statewide Universal Basic Income[7]	Adjust income distribution results outside REMI model
	Expand Job Training and Incubator Programs	Increase investment in manufacturing and education sectors
ENVIRONMENT	Adapt to Sea Level Rise	Increase investment in construction sector
	Provide Means-Based Financial Support to Retrofit Existing Residential Buildings	

7 The UBI strategy replaced the Childcare Subsidy strategy after the Draft Blueprint and the latter was modeled as part of the Regional Growth Forecast. However, staff expects the net impact of the Childcare Subsidy strategy on the region's economy and demographics to be negligible.

Transportation Strategies

The economic impact of transportation investments generally fits into two categories: (1) direct effects from spending — in operations and maintenance (O&M)[8] and construction of new projects – as well as multiplier effects; (2) enhanced economic competitiveness through improved network efficiency and congestion reduction (which reduces cost for businesses), as well as improved air quality and quality of life. While staff recognized the importance of capturing the comprehensive effects of the proposed transportation strategies, the forecast only considered the impact in the first category due to limited model capacities. Therefore, the forecast reflects a more conservative estimate of the transportation spending in the plan.

Seven of the transportation strategies include major investments in transportation infrastructure. These strategies were represented in the Regional Growth Forecast as increased demand within the construction industry and increased government administrative spending. The strategies were:

- T1: Restore, Operate and Maintain the Existing System
- T6: Improve Interchanges and Address Highway Bottlenecks
- T7: Advance Other Regional and Local Transit Projects
- T8: Build a Complete Streets Network
- T10: Enhance Local Transit Frequency, Capacity and Reliability
- T11: Expand and Modernize the Regional Rail Network
- T12: Build an Integrated Regional Express Lanes and Express Bus Network.

For the transportation strategy T4: Reform Regional Transit Fare Policy, staff anticipated that a $10 billion means-based fare discount, funded through existing transportation revenues, would increase transit subsidies, and allow for consumer spending reallocation (i.e., money saved would be spent on other commodities). In contrast, staff represented strategy T5: Implement Per-Mile Tolling on Congested Freeways with Transit Alternatives as a reduction in personal income.

Housing Strategies

Housing strategies are designed to spur housing production as well as to protect and preserve affordable housing. Boosting housing capacity is addressed through strategic zoning changes, seeking to support the development of housing throughout the region where appropriate. Staff assumed these zoning change-related strategies would allow and encourage private construction investment for market rate housing, which would help the region reach the goal of driving down its 2050 average housing cost, affecting the overall regional growth trajectory significantly. As mentioned in the Regional Growth Forecast and Land Use Model Interaction section, this was modeled in REMI by adjusting the relative housing price variable downward starting in 2022 so that by 2050 Bay Area home price relative to the U.S. would be back to 2001 levels.[9] Additionally, the level of residential construction investment was increased in the model based on expected housing development. Staff estimated the set of strategies to fund affordable housing protection, preservation, and production would allow consumer spending reallocation (95% of the subsidy provided) and increase government administrative spending (remaining 5%).

Economic Strategies

Economic strategies are primarily focused on improving economic mobility and shifting the location of jobs. Two of the strategies that are designed to improve economic mobility are included in the regional economic model: EC1: Implement a Statewide Universal Basic Income (UBI); and EC2: Expand Job Training and Incubator Programs. Other strategies designed to shift location of jobs are represented in the land use and travel models, but not reflected in the Regional Growth Forecast.

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8 O&M is where most of the forecasted transportation revenues will be spent. Staff considers the current level of operations and maintenance spending sufficient to maintain existing conditions of the region's transportation assets. Therefore, staff did not simulate the impacts of these baseline investments separately. However, in cases where there are additional revenues to improve the condition beyond today's levels or to fund operations and maintenance demand necessitated by new projects, staff modeled the impacts of these investments.

9 Because in REMI, historical data dates to only 2001, relative housing price index of year 2001 level was used instead of the 2000 level.

Strategy EC1: Implement a Statewide Universal Basic Income is costly but provides many benefits to low and low-to-moderate income households. While the model's ability to capture the full effects of the UBI strategy is limited, staff tested the strategy in the REMI model through an increase in both taxation and spending, which resulted in a minimal to neutral economic impact. Given that the purpose of the strategy is to improve economic mobility, in the end staff updated the income distribution results outside the REMI model to represent its impact. Strategy EC2: Expand Job Training and Incubator Programs is represented by increasing investment in the manufacturing and education industries.

Environmental Strategies

Strategy EN1: Adapt to Sea Level Rise focuses on protecting the shoreline as well as critical transportation infrastructure in areas at risk. To the extent that there would be increases in capital projects spending such as building levees and infrastructure enhancements, staff increased demand for the construction industry using the REMI model.

Strategy EN2: Provide Means-Based Financial Support to Retrofit Existing Residential Buildings is estimated to cost $15 billion, of which staff assumed that $12 billion[10] was directly invested into the construction industry in the model. This was not modeled as increased consumer spending because staff assumed that without the subsidies, homeowners would not be incentivized to retrofit existing building at all.

Revenues to Fund Plan Strategies

Staff assumed that the current levels of government funding for programs, including transportation operations, maintenance, and investment will continue. Funding for the strategies included in the REMI model would be generated by additional taxes.

For the purposes of the Regional Growth Forecast, staff assumed that:

- Additional transportation revenues would be generated by a sales tax increase;
- Additional housing revenues would be generated by a business tax increase;
- Additional economic revenues would be generated by a personal income tax increase; and
- Additional environment revenues would be generated by a property tax increase.

10 The Draft Blueprint assumed a total cost of $20 billion for this strategy, and the $12 billion investment in the construction industry was based upon this assumption. While the Final Blueprint/Plan adjusted the total down to $15 billion, the $12 billion investment in the construction industry remained unchanged.

Households

In the Regional Growth Forecast, households are closely related to the age, racial and ethnic composition of the population, reflecting important patterns of how households are formed in relation to demographic features. Typically, young adults leave the home or migrate to an area and form their own households or share housing with others. For young adults, it is common to see relatively higher average household sizes. Some will pair up and form families, often with two adults in a household. Life events, such as divorce or loss of a partner in later years will be result in fewer adults per household in the upper half of the population age distribution. While children make up a sizeable chunk of the population, they only indirectly impact the number of households formed, and units occupied. The typical accounting framework relates the number of households to the number of adults: headship rates.

Headship rates, while serving to capture the propensity for a given group of adults to form households, also reflect a larger set of behavioral and economic conditions in a region, for which reason these rates vary between regions, and over time. Some ethnic groups are more prone to multi-generational households, which will be reflected in the headship rates. Further, in regions with higher housing costs, the propensity to form households is slightly lower than in more affordable regions. To project a future number of households, accordingly, staff needs information about the future population and its age and racial/ethnic structure.

Headship rates can change over time as behavior or economics change. As housing affordability is currently at historically low levels in the Bay Area and one of the plan goals is to increase housing affordability, current headship rates were assumed to represent a constrained housing market. With a proactive state and regional housing policy framework adjusting the capacity for housing, more households would be able to form than would be the case today. To practically reflect this, headship rates were set to transition from today's constrained levels to rates observed two decades ago, in effect "rolling back" the clock on the housing market.

Headship rates were set to vary by year, starting with observed rates from ACS 2012-2016 sample, and then transitioned to the somewhat higher rates found in Census 2000 Public Use Microdata Sample (PUMS). As this change took place over more than a decade, it was assumed this transition to a more accommodating housing market and associated household formation regime would take a more than a decade and a half – with a few years to allow for policy to become effective. Rates were thusly transitioned from existing rates starting in 2022, and gradually rolled back to 2000 levels, with the transition assumed to be complete by 2038. The practical effect of this is for a given population, a slightly larger number of households would result, reflecting a healthier and more dynamic housing market.

The rates are applied to the forecasted future household population, where the household population is segmented into the four racial/ethnic groups accounted for in REMI: Hispanic/Latinx; White, Not Hispanic; Black, Not Hispanic, and Other, Not Hispanic. The household population is further broken down into 15 five-year age groups, beginning at 15, and ending at 85 and over for a total of 60 age/ethnic and racial groups. The detailed headship rates for the years 2015, 2030 and 2050 for the final forecast are provided in Table 6. For many age groups, a small increase of rates can be observed from 2015 to 2050.

Table 6. Headship rates, by year, age group, race/ethnic group

RACE / ETHNICITY	BLACK-NON-HISPANIC			HISPANIC			OTHER-NON-HISPANIC			WHITE-NON-HISPANIC		
Age Group	2015	2030	2050	2015	2030	2050	2015	2030	2050	2015	2030	2050
Ages 15-19	0.02	0.02	0.03	0.01	0.02	0.02	0.01	0.02	0.03	0.01	0.01	0.02
Ages 20-24	0.14	0.18	0.23	0.11	0.12	0.15	0.13	0.15	0.18	0.15	0.19	0.25
Ages 25-29	0.32	0.36	0.43	0.24	0.26	0.29	0.27	0.28	0.30	0.34	0.38	0.44
Ages 30-34	0.40	0.44	0.51	0.37	0.38	0.39	0.40	0.41	0.42	0.47	0.49	0.51
Ages 35-39	0.48	0.51	0.56	0.41	0.42	0.44	0.47	0.46	0.44	0.51	0.52	0.54
Ages 40-44	0.54	0.55	0.58	0.45	0.46	0.49	0.48	0.48	0.48	0.53	0.54	0.56
Ages 45-49	0.56	0.57	0.60	0.48	0.49	0.51	0.50	0.50	0.50	0.56	0.57	0.58
Ages 50-54	0.61	0.62	0.65	0.49	0.50	0.51	0.49	0.49	0.49	0.57	0.58	0.60
Ages 55-59	0.58	0.61	0.65	0.49	0.50	0.51	0.48	0.48	0.49	0.58	0.59	0.61
Ages 60-64	0.64	0.66	0.69	0.49	0.49	0.49	0.44	0.45	0.46	0.60	0.61	0.64
Ages 65-69	0.67	0.68	0.70	0.48	0.48	0.49	0.44	0.44	0.43	0.62	0.64	0.66
Ages 70-74	0.74	0.74	0.75	0.51	0.52	0.54	0.43	0.43	0.44	0.65	0.66	0.67
Ages 75-79	0.72	0.73	0.75	0.49	0.53	0.59	0.44	0.45	0.47	0.66	0.68	0.70
Ages 80-84	0.66	0.69	0.73	0.53	0.54	0.55	0.44	0.47	0.52	0.70	0.72	0.74
Ages 85+	0.68	0.69	0.70	0.54	0.54	0.54	0.48	0.48	0.49	0.75	0.76	0.77

NOTE: Headship rates vary by year, starting with observed rates from U.S. Census Bureau, American Community Survey 2014-2018 sample, and are transitioned to higher rates found in U.S. Census Bureau, Census 2000 PUMS. Transition is from 2022-2038. Data is for the nine-county San Francisco Bay Area.

Income

After household counts have been projected, they are disaggregated further into income groups. Household income is an important predictor for housing location choices as well as travel behavior and is thus important to downstream analyses. The income distribution analysis considers structural characteristics of the region including demographic factors such as the age profile and ethnic mix, and economic factors such as the predominant industries and occupations in which people work, as well as the various sources of income (retirement income, public assistance income, wage and salary income) observed in the aggregate. The core translation performed is one where such overall factors of a regional economy are related to the share of households in each of four income groups. The relationship is based on observed county-level data for the nation's largest metropolitan areas, where economic and demographic variables serve as predictors of the relative shares in different household income groups.

The income categories are defined below. They were originally defined as approximate quartiles in 2000 dollars because that is the year of currency used in the Travel Model. Over the years as income inequality has risen, they have morphed into quantiles. The income quantiles presented below are used throughout the remainder of this report.

Table 7. Income quantile definitions used in the modeling system

QUANTILE	2000 DOLLARS	2020 DOLLARS
Q1: low-income	Less than $30,000	Less than $50,000
Q2: moderate-low-income	$30,000 to $60,000	$50,000 to $100,000
Q3: moderate-high-income	$60,000 to $100,000	$100,000 to $170,000
Q4: high-income	More than $100,000	More than $170,000

The relationship between regional economic performance and the distribution of incomes is complex and dependent on not just compensation practices but also how people group together to form households, decide whether to hold a job or retire, raise children, and a host of other considerations. These decisions themselves will vary over time, but there is much than can be seen from the data available. All other things equal, for example, locations with a relatively large share of management occupations may be expected to have more upper income households, while locations with a higher proportion receiving public assistance may conversely be expected to have more low-income households.

To capture such relationships, staff specified four regression models (using data from ACS at the county level) on the relationship between demographic and economic variables and share of households in each of the four income quartiles defined above, with a generally good fit.[11] These relationships are carried forward, with data from REMI on the future economy (employment, age, industry, occupation) used to predict the relative share of households in the four income groups, and those shares are applied to the projected household counts.

11 Because ordinary least squares (OLS) regressions are not limited to the range between 0 and 1, the predicted shares from the four models are scaled to sum to 100%, and the predicted shares are indexed to 2015 observed levels. The projection then moves the observed levels up or down depending on the index.

Findings: Regional Growth Forecast Results

Table 8 shows both the baseline forecast and the Plan Bay Area 2050 Final Regional Growth Forecast. The baseline forecast does not integrate regional strategies and represents a "status quo" future where regional goals such as affordability would not be achieved, in conflict with state requirements to fully accommodate future regional growth and affordability objectives established in the adopted Plan Bay Area 2050 Guiding Principles. As discussed previously, the Final Regional Growth Forecast incorporates the impacts of regional strategies on the region's economy, demographics and households.

In the Final Regional Growth Forecast, between 2015 and 2050, the region's employment is projected to grow by 1.4 million to just over 5.4 million total jobs. Population is forecasted to grow by 2.7 million people to 10.3 million. This population will comprise over 4.0 million households, for an increase of nearly 1.4 million households from 2015. The number of housing units is projected to grow by 1.5 million units. Compared to the baseline forecast, integrating the regional strategies and fully accommodating future residents led to 300,000 more jobs, 760,000 more people, 460,000 more households, and 480,000 more housing units.

Table 8. Plan Bay Area 2050 Baseline Forecast and Final Regional Growth Forecast

	2015	2020	2025	2030	2035	2040	2045	2050
BASELINE FORECAST								
Total Population	**	**	8,130,000	8,360,000	8,700,000	9,040,000	9,330,000	9,570,000
Total Employment	**	**	4,050,000	4,530,000	4,680,000	4,850,000	4,980,000	5,110,000
Total Households	**	**	2,930,000	3,080,000	3,230,000	3,370,000	3,490,000	3,580,000
Total Housing Units	**	**	3,050,000	3,240,000	3,400,000	3,550,000	3,670,000	3,770,000
FINAL REGIONAL GROWTH FORECAST								
Total Population	7,660,000	7,940,000	8,230,000	8,560,000	9,010,000	9,490,000	9,930,000	10,330,000
Total Employment	4,010,000	4,080,000	4,150,000	4,640,000	4,830,000	5,050,000	5,230,000	5,410,000
Total Households	2,680,000	2,760,000	2,950,000	3,210,000	3,500,000	3,710,000	3,890,000	4,040,000
Total Housing Units	2,710,000	2,840,000	3,060,000	3,370,000	3,670,000	3,900,000	4,080,000	4,250,000

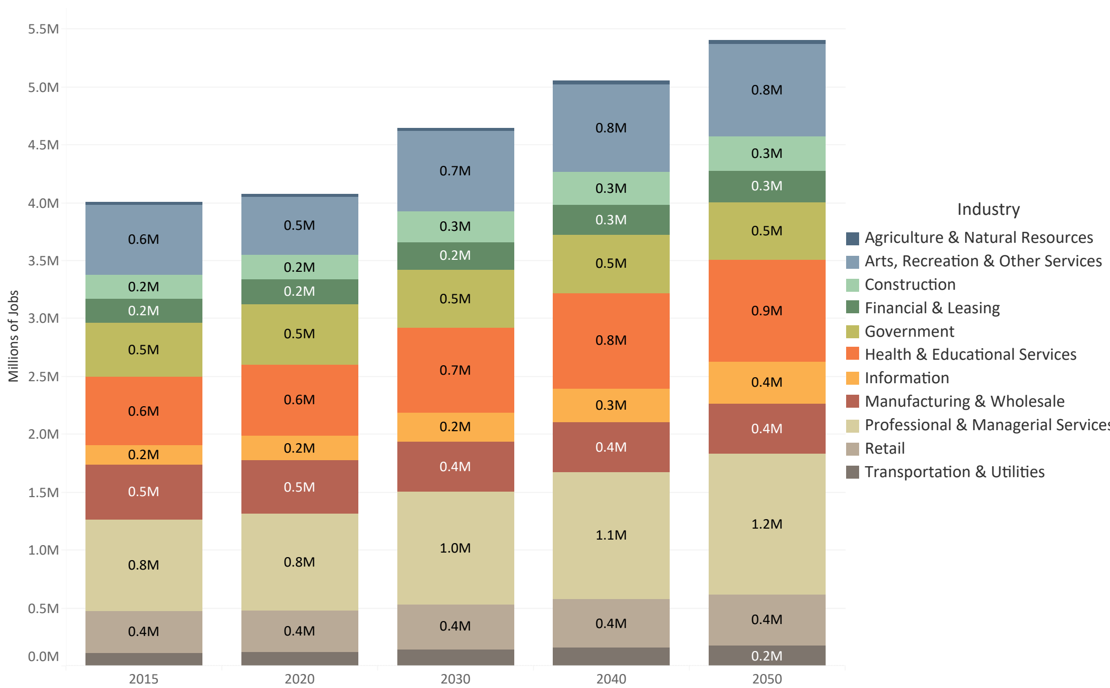
** = See Final Regional Growth Forecast below.

The Final Regional Growth Forecast projects approximately 400,000 more jobs, 200,000 fewer people, 300,000 more households and 300,000 more housing units in 2040 compared to the Plan Bay Area 2040 forecast. There are several reasons for the difference in the forecasts between Plan Bay Area 2040 and this latest forecast for the Bay Area. Differences in population are largely due to the assumption that the recent observed decline in Hispanic international migration and birth rates would continue, which is consistent with U.S. Census Bureau and California Department of Finance assumptions. Second, strong employment growth during the 2010s has resulted in adjustments to the early years of the forecast, and as a result the endpoint of the trend is also higher. Meanwhile, comparing the age composition of the population in these two forecasts, this forecast has a higher number of older adults, who usually have higher headship rates, forming more households. Finally, this forecast integrated housing strategies that would encourage more housing production and investment, resulting in higher household and housing unit numbers, as well as creating more jobs.

Employment Growth and Change

Figure 2 compares the level and distribution of employment in 2015 to projected employment in future years up to 2050. Professional and managerial services, and health and educational services are forecasted to continue dominating future employment in the San Francisco Bay Area, and the information sector more than doubles its current job numbers. Meanwhile, despite increases in both output and demand in all sectors as well as proposed strategies intended to stimulate employment in certain industries, the forecast shows declining employment in a few sectors, due to both technologically induced higher productivity and changes in economic structure, particularly in the manufacturing and wholesale industries. Finally, job forecasts both for construction as well as transportation and warehousing are boosted by the infusion of investments.

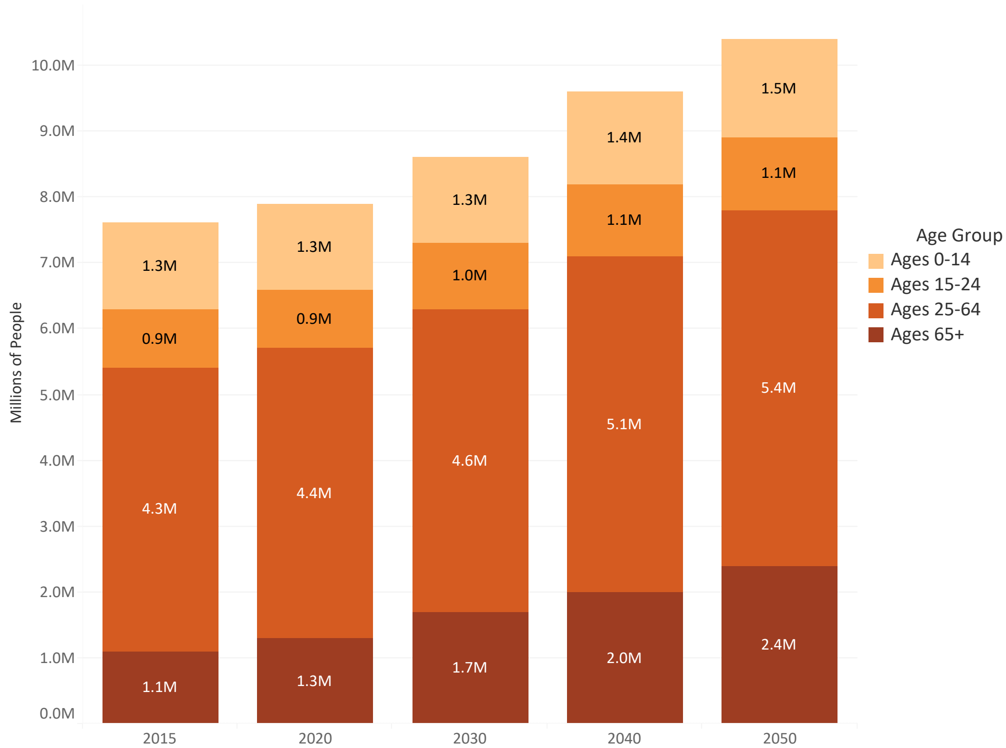
Figure 2. Employment by sector in the Regional Growth Forecast



Population Growth and Change

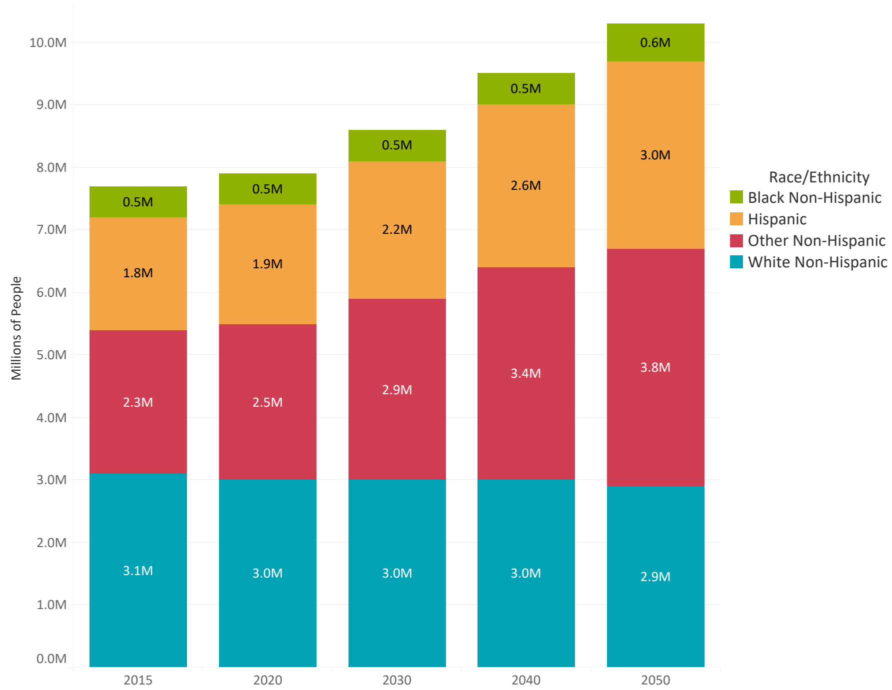
Figure 3 compares the population by age group in 2015 with that of the projections for future years up to 2050. Between 2015 and 2050, the number of working-age adults is forecasted to grow by 25%, but the share declines by 4% (from 56% to 52%). The growth in the share of people in the 65+ age group is anticipated to continue in the decades ahead from 14% of the total population in 2015 to 23 percent in 2050. While the 2050 total population is projected to be 35% higher than in 2015, growth will differ widely by age group.

Figure 3. Population by age group in the Regional Growth Forecast (in millions)



Ethnically, the region continues to diversify over time, as shown in Figure 4. Growth takes place mainly in Hispanic and Asian racial/ethnic groups (the largest group within the Other Non-Hispanic category in the figure). There is a small increase in the Black Non-Hispanic population, while the White Non-Hispanic population decreases steadily over time. By 2050, Asian, Native American, Pacific Islander, and More than One Racial group will reach 4 million people, while the Hispanic population will grow to the same level as White Non-Hispanic: around 3 million people.

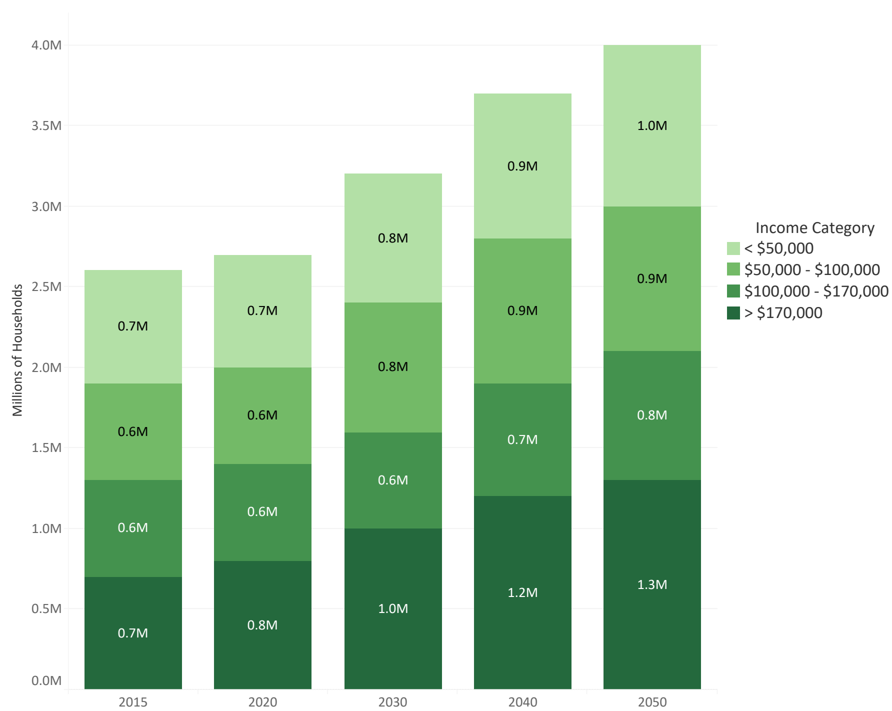
Figure 4. Population by race/ethnicity in the Regional Growth Forecast (in millions)



Household Income Distribution

Figure 5 compares the household income distribution in 2015 with the projected income distribution for future years. The amount of household growth projected (1.4 million new households between 2015 and 2050) reflects strategies that encourage both market rate and affordable housing development, increasing the number of housing units produced.

Figure 5. Projected income distribution of households in the Bay Area (in millions; income segments are in 2020 dollars[12])



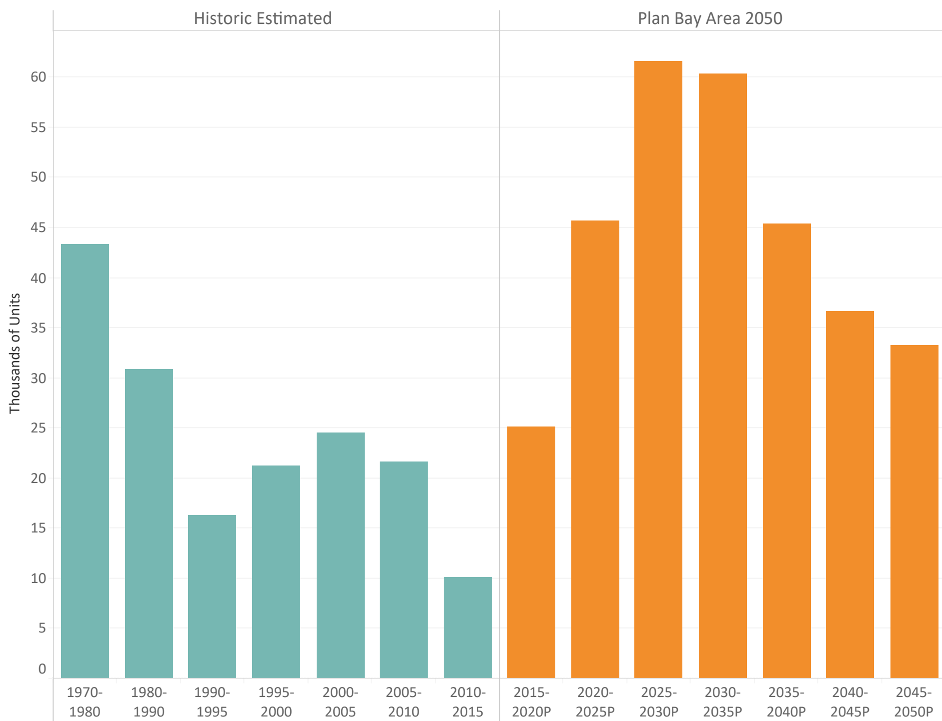
12 See Table 7: Income quantile definitions used in the modeling system.

While the number of households in all four income categories is expected to grow, household growth is anticipated to be strongest in the highest income category, reflecting the expected strength of growth in high-wage sectors combined with non-wage income (interest, dividends, capital gains, transfers). Household growth is also anticipated to be high in the lowest-income category, reflecting possible occupational shifts, wage stagnation, the retirement of seniors without pension assets, as well as the proposed affordable housing strategies. However, with the assumed implementation of a statewide Universal Basic Income strategy starting in 2025, portions of the households in the lowest-income category would be able to move up to the mid-lower income category.[13]

Housing Production

To translate growth in households to the anticipated demand for housing units, staff assumed a healthy vacancy rate for the region of five percent beginning from 2030[14] — leading to a projected increase of housing units by 1.5 million through 2050; the level of demand for new housing units follows the formation of new households. The forecast implies an annual average rate of increase of between 25,000 and 61,000 units, depending on the time period. As shown in Figure 6, this means a significant increase of production for the next three decades to a level of production above that of 1970s and 1980s, which requires the region successfully implement the housing strategies proposed in the plan.

Figure 6. Annual housing production, historic and projected (in thousands of housing units)



The Regional Housing Control Total in the Plan Bay Area 2050 Final Regional Growth Forecast, also known as the year 2050 total housing units projection, reflects the "Backward Arrow" linkage described previously which captures the impact of increasing housing supply at all income levels and lowering housing prices. The number also implies a much healthier housing market in the Bay Area compared to today's levels: higher headship rates, lower household size, healthier vacancy rate, improved job-housing ratio, and an affordable housing stock — nearly a quarter of the housing stock in 2050 would be deed-restricted affordable housing units in the Plan.

13 Although the UBI subsidies would be provided to households of all income groups, staff anticipate that the funding would come from a tax on households that not in the lowest-income category. That is to say, the net impact would only be a portion of the households in the lowest-income category would move up to mid-low-income category. According to PUMS 2014-2018 data, 11.6% of the lowest-income category households have such a level of income the UBI subsidies would push them over the income threshold to mid-low-income category. Staff assumes the ratio remains consistent, moving 11.6% lowest-income households into mid-low-income group in the pre UBI forecast results from 2025 to 2050 to simulate the impacts of the UBI.

14 California Department of Finance estimates of Bay Area vacancies have varied from 3.4% to 6.4% since 2000. Current vacancy rate stands around 3%.

Overall, the Regional Growth Forecast provides enough housing and making it affordable for the in-commuters who today are forced to live outside the region due to high housing cost or a lack of housing choices to move into the region in the future, thereby reducing the number of in-commuters. This amount is more than sufficient to preclude the need for a separate in-commute adjustment. Both the potential in-commuters and many additional potential residents who would have been excluded from living in the region or even the megaregion due to the Bay Area's high housing prices would be accommodated within the nine-county region through strategies in Plan Bay Area 2050.

Chapter 3 | Land Use Model

This section provides a high-level overview of the Bay Area UrbanSim 2 Land Use Model application. The model provides a consistent, theoretically grounded means of forecasting land use change in the Bay Area for the Regional Forecast's household and employment totals and planning strategies that are incorporated into the Plan and EIR Alternatives. In addition, Bay Area UrbanSim 2 is integrated with Travel Model 1.5 to address the interactions between transport system changes and land use changes. This section includes an overview of the model structure, simulation sub-models and a brief introduction to the alternatives. Interactions between the BAUS2 and the other modeling components are described in the Model System Overview.

Bay Area UrbanSim 2 Land Use Model Application

UrbanSim is a modeling system developed to support the need for analyzing the potential effects of land use policies and infrastructure investments on the development and character of cities and regions. UrbanSim has been applied in a variety of metropolitan areas in the United States and abroad, including Detroit, Eugene-Springfield, Honolulu, Houston, Paris, Phoenix, Salt Lake City, Seattle, and Zürich. The application of UrbanSim for the Bay Area (i.e., Bay Area UrbanSim) was originally developed by the Urban Analytics Lab at UC Berkeley under contract to MTC and further refined (up to the current Bay Area UrbanSim 2) by MTC and ABAG modeling staff.[15]

The area included in the Bay Area model application includes all incorporated and unincorporated areas of the nine-county Bay Area.[16] This geographic area defined the scope of the data collection efforts necessary to define the modeling assumptions. Bay Area UrbanSim 2 is based on legal parcels of land drawn from 2010 data and updated with new information to match the 2015 base year used across the model system.

Within Bay Area UrbanSim 2 there are 10 sub-models simulating the real-world choices and actions of households, businesses, and real estate developers within the region, based on assumed public-sector strategies (i.e., policies or investments). Households have particular characteristics such as income that may influence preferences for housing of different types at different locations. Businesses also have preferences that vary by industry for building types and locations. Developers construct new buildings or redevelop existing ones in response to demand and planning constraints, such as zoning. Buildings are located on land parcels that have particular characteristics such as value, land use, topography, and other environmental qualities. Governments set policies that regulate the use of land, through the imposition of land use plans, urban growth boundaries, environmental regulations, or through pricing policies such as development impact fees or subsidies. Governments also build infrastructure, including transportation infrastructure, which interacts with the spatial distribution of households and businesses to generate patterns of accessibility at different locations that in turn influence the attractiveness of these sites for different consumers.

The Bay Area UrbanSim 2 model system simulates these choices through the sub-models described below and shown Figure 7, Figure 8 and Figure 9. These figures also show how the travel model and Bay Area UrbanSim 2 interact. Several of the system models include algorithms that aim to match the total number of units (e.g., jobs, households) included in the Regional Growth Forecast. These totals are checked at the end of each model year run. In each of Bay Area UrbanSim 2's five-year predictions, the model system steps through the following components:

1. The **Employment Transition Model** predicts new businesses being created within or moved to the region, and the loss of businesses in the region – either through closure or relocation out of the region. The role of this model is to keep the number of jobs in the simulation synchronized with aggregate expectations of employment in the region.

2. The **Household Transition Model** predicts new households migrating into the region, the loss of households emigrating from the region, or new household formation within the region. The Household Transition Model accounts for changes in the distribution of households by type over time, using an algorithm analogous to that used in the Employment Transition Model. In this manner, the Household Transition Model keeps Bay Area UrbanSim household counts synchronized with the aggregate household projection.

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15 More information on UrbanSim is available at http://urbansim.com.

16 Technical information on Bay Area UrbanSim 2 can be found at https://github.com/BayAreaMetro/bayarea_urbansim.

3. The **Real Estate Development Model** simulates the location, type, and density of real estate development, conversion, and redevelopment events at the level of specific land parcels. This sub-model simulates the behavior of real estate developers responding to excess demand within land use policy constraints. The algorithm examines a subset of parcels each forecast year and builds pro formas comparing development costs and income. New structures are built in profitable locations.

4. The **Scheduled Development Events Model** provides an alternative means for the introduction of new buildings into the region. This component is simply a list of predetermined structures to be built in specific future years. These are from three categories: 1) recently completed development or projects under construction; 2) large, committed but unbuilt, public-private partnership projects (examples shown in Table 9); 3) special strategy-driven developments such as the mall-office park and public land strategies described below.

5. The **Employment Relocation Model** predicts the relocation of business establishments (i.e., specific branches of a firm) within the region each simulation year. The Employment Relocation Model predicts the probability that jobs of each type will move from their current location to a different location within the region or stay in place during a particular year.

6. The **Household Relocation Model** predicts the relocation of households within the region each simulation year. For households, mobility probabilities are based on the synthetic population from Travel Model 1.5. Drawn from Census data, these rates reflect the tendency for younger and lower income households to move more often.

7. The **Government Growth Model** uses a set of rules to project the employment in non-market sectors such as government and schools based on historical employment in those sectors and projected local, sub-regional, and regional population growth.

8. The **Employment Location Choice Model** predicts the location choices of new or relocating establishments. In this model, we predict the probability that an establishment that is either new (from the Employment Transition Model), or has moved within the region (from the Employment Relocation Model), will be located in a particular employment submarket. Each job has an attribute of the amount of space it needs, and this provides a simple accounting framework for space utilization within submarkets. The number of locations available for an establishment to locate within a submarket will depend mainly on the total vacant square footage of nonresidential floor space in buildings within the submarket, and on the density of the use of space (square feet per employee). This sub-model simulates the behavior of businesses moving to suitable locations within the region.

9. The **Household Location Choice Model** predicts the location choices of new or relocating households. In this model, as in the business location choice model, we predict the probability that a household that is either moving into the region (from the Household Transition Model), or has decided to move within the region (from the Household Relocation Model), will choose a particular location defined by a residential submarket. This sub-model simulates the household behavior in selecting a neighborhood based on their sociodemographic preferences.

10. The **Real Estate Price Model** predicts the price per unit of each building. UrbanSim uses real estate prices as the indicator of the match between demand and supply of land at different locations and with different land use types, and of the relative market valuations for attributes of housing, nonresidential space, and location. This role is important to the rationing of land and buildings to consumers based on preferences and ability to pay, as a reflection of the operation of actual real estate markets. Since prices enter the location choice utility functions for jobs and households, an adjustment in prices will alter location preferences. All else being equal, this will in turn cause higher price alternatives to become more likely to be chosen by occupants who have lower price elasticity of demand. Similarly, any adjustment in land prices alters the preferences of developers to build new construction by type of space, and the density of the construction.

Figure 7. UrbanSim model flow: employment focus

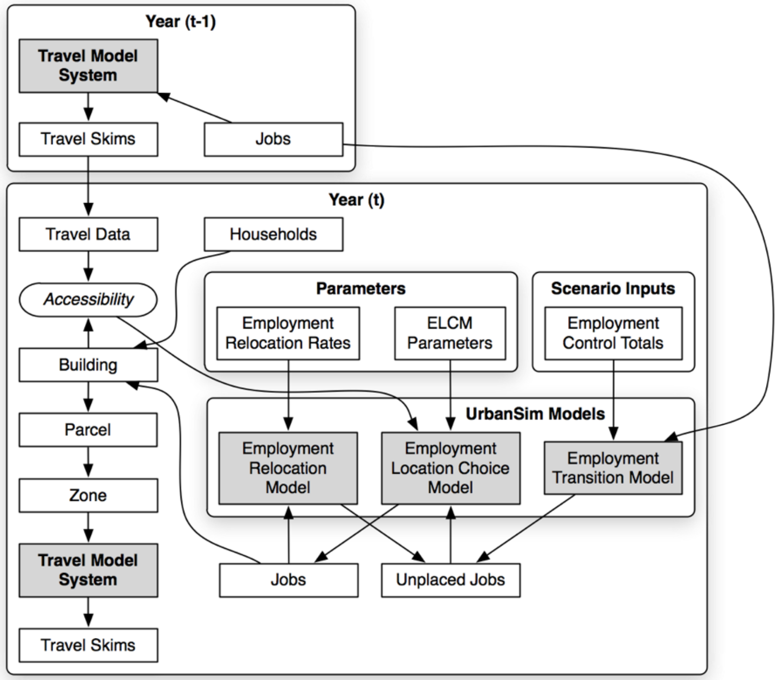

Figure 8. UrbanSim model flow: household focus

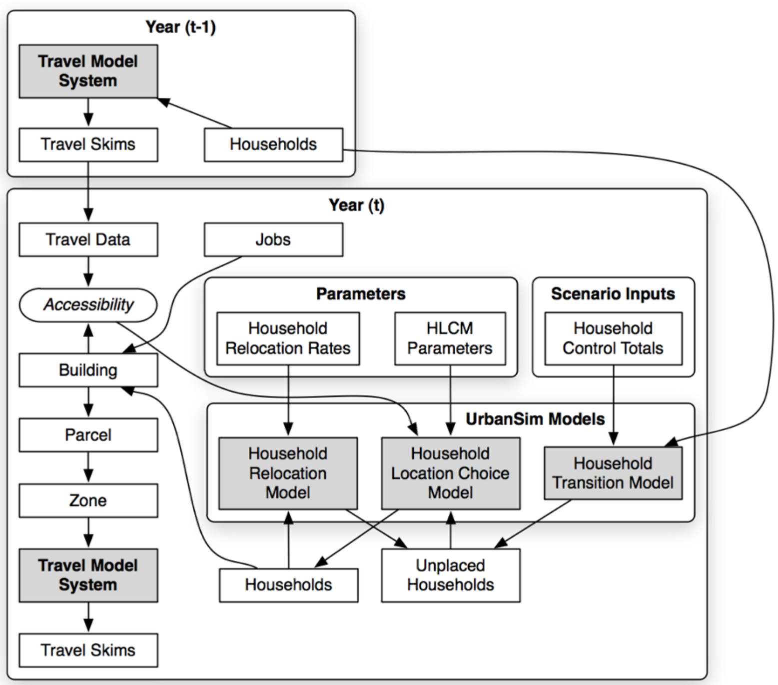

Figure 9. UrbanSim model flow: real estate focus

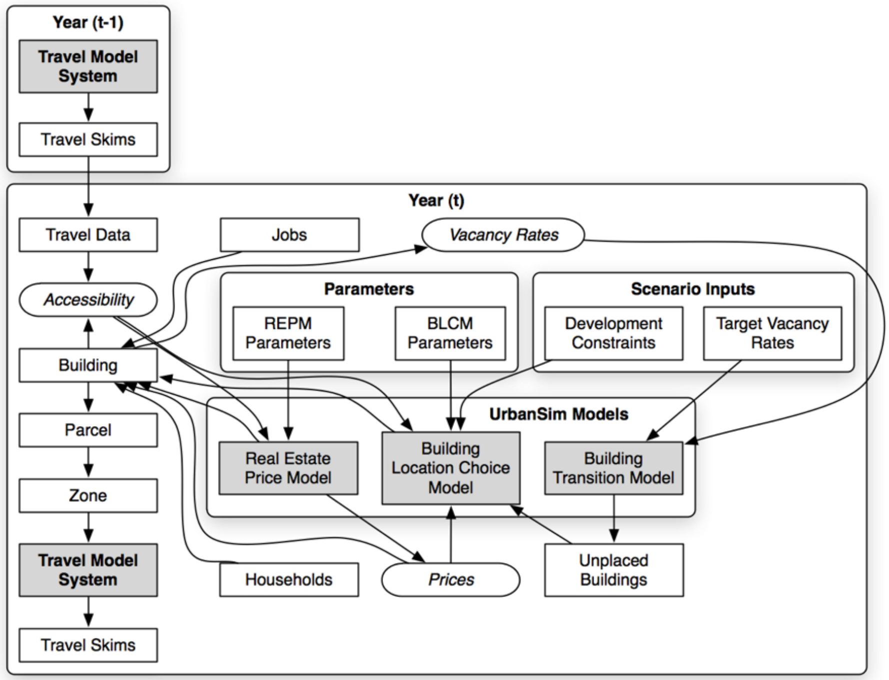

Table 9. Examples of scheduled development events

SCHEDULED DEVELOPMENT EVENT	
MacArthur BART Transit Village Construction	Park Merced Redevelopment
South Hayward BART Transit Village Construction	San Francisco General Hospital Expansion
Concord Community Reuse Construction	Transbay Terminal Redevelopment
Lawrence Berkeley Lab 2 Construction	Treasure Island Construction
Pleasant Hill BART Transit Village Construction	Bay Meadows Construction
Richmond BART Transit Village Construction	Kaiser Redwood City Expansion
Walnut Creek Transit Village Construction	Sequoia Hospital Expansion
Hunters Point Naval Shipyard Construction	Stanford Medical Center Expansion
Mission Bay Construction	Berryessa BART Transit Village Construction
Moscone Center Expansion	

Each of Bay Area UrbanSim 2's components were estimated individually and then assembled into a comprehensive system that is calibrated and reviewed. The household and employment transition models were simply an outcome of the regional totals divided into annual increments. The relocation models probabilities derived from Census and time series establishment data. The household and employment location choice models were estimated using logit models describing current locations as a function of various factors. The real estate price models are hedonic regressions that were built using recent residential transaction records and commercial rents. Finally, the real estate development model was assembled using output from the other components, industry estimates for building costs, and standard financial assumptions.

Once the components were functioning, Bay Area UrbanSim 2 was run. The forecast output was then compared to historical growth patterns and opportunities for feedback by planners at MTC and ABAG, the Regional Modeling Working Group, and local jurisdictions were provided at key points in 2020.

Input Assumptions

This section describes the Bay Area UrbanSim 2 base year database and assumptions for the various EIR Alternatives. Key variables, data sources, and processing steps are described, and selected variables are profiled or mapped to illustrate trends and assess reasonableness. While the year 2015 was selected as the base year for overall model system, the land use forecast begins from the year 2010 because both a complete parcel dataset and high-resolution census data were available for that year. Additional data updates were incorporated within the first model forecast step in 2015. The Bay Area UrbanSim 2 application operates at the level of individual households, jobs, buildings, and parcels. Jobs and households are linked to specific buildings, and buildings are linked to parcels.

In the sections below, there are tables of the base distribution of employment, population, and buildings in the Bay Area. In some cases, incomplete or inconsistent data was imputed using more-aggregate household or employment counts. The base-year database contains around 2.7 million households (not including group quarters), 4.0 million jobs, 1.9 million buildings, and 2 million parcels, based on information from the U.S. Census, Dun & Bradstreet establishment data, the CoStar commercial real estate database, and county assessor parcel files.

Base Year Spatial Database

Bay Area UrbanSim 2 uses a detailed geographic model of the Bay Area. A geographic information system was used to combine data from a variety of sources to build a representation of each building and property within the region. These detailed spatial locations are grouped into TAZs to improve model flow and provide summary output. Because this database represents the current state of the Bay Area's land use pattern, it is used as an identical starting point for all four alternatives.

Bay Area Spatial Information System (BASIS)

The Bay Area Spatial Information System (BASIS)[17], a new Data as a Service (DaaS) initiative operated by MTC and ABAG beginning in 2020, brought key regional datasets onto an industry standard DaaS platform where users internal and external to MTC and ABAG could download it, or access it via API for analysis and modeling purposes. BASIS represents an evolution of past efforts, such as the Local Policy Development Survey (2005), that sought to collect data from local jurisdictions for use in regional forecasts, and long-range planning activities for the nine county San Francisco Bay Area region.

A key component of BASIS included a robust review and feedback system that collected invaluable feedback from local jurisdictions, key regional stakeholders and staff within MTC and ABAG. BASIS presented the data for review by local jurisdictions in an inventory format that allowed local jurisdictions to select a location and retrieve a summary of the data available at that location. The summary was associated with a count of parcels that contain any one or more of the land use, transportation, or development characteristics that are tracked as part of Housing Development Tracking, Transportation and Land Use Modeling (Bay Area UrbanSim 2).

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17 Bay Area Spatial Information System (BASIS): https://basis.bayareametro.gov.

The BASIS effort offered four key benefits for MTC and ABAG's understanding of development capacity:

- A secure, accessible database platform for the collection, standardization, discovery, and dissemination of key datasets used in regional planning efforts,
- A well-documented, organized, and definitive source of regional data,
- A single source of information that tracks trends associated with development conditions, land use, and environmental impacts associated with future growth and changes to the physical landscape, and
- A common framework to discuss and plan for future growth in the region.

Parcels

Parcels, or individual units of land ownership, provide a fundamental building block for the Bay Area UrbanSim 2 model: in both the real world and the model they are the entity that is owned, sold, developed, and redeveloped by households and businesses. In a given year, each parcel is associated with 0, 1, or multiple buildings that provide space for activities. The UrbanSim parcel database includes information linking the parcels to zones they are within, buildings that are on them, their size, their monetary value, and their current planning constraints.

Buildings

The base year database contains around 2 million buildings categorized into 14 different types as seen in Table 10. Households and businesses are assigned to buildings and buildings are linked to a parcel. Each building has attribute information on its size, age, and value, among other characteristics. Building attributes are primarily sourced from 2010 parcel assessor's data, updates on new construction provided by the BASIS process, and commercial real estate databases. The building database is modified by the Real Estate Development Model as it tears down buildings and constructs new buildings. Figure 10 and Figure 11 map out illustrative building attributes at the zonal level.

Table 10. Building types and 2015 counts in Bay Area UrbanSim 2

BUILDING TYPE	2015 COUNT
Single Family Detached	1,494,017
Single Family Attached	207,385
Multi-Family	103,423
Office	37,755
Hotel	2437
School	3184
Light Industrial	21,543
Warehouse	11,067
Heavy Industrial	1542
General Retail	43,328
Big-Box Retail	1840
Mixed-Use Residential	7467
Mixed-Use Retail-Focus	1379
Mixed-Use Employment-Focus	736

Figure 10. Percent single family residential buildings by TAZ

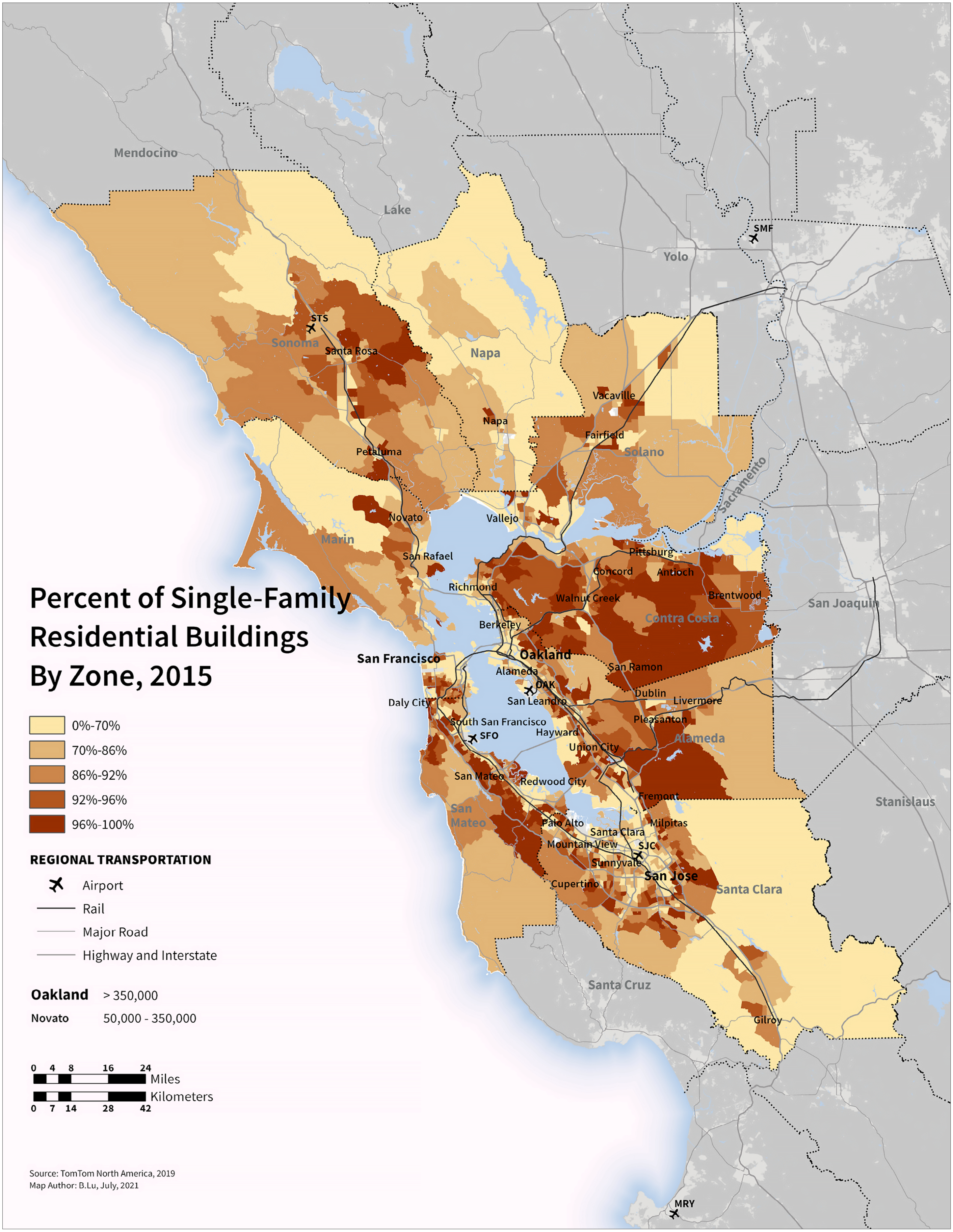
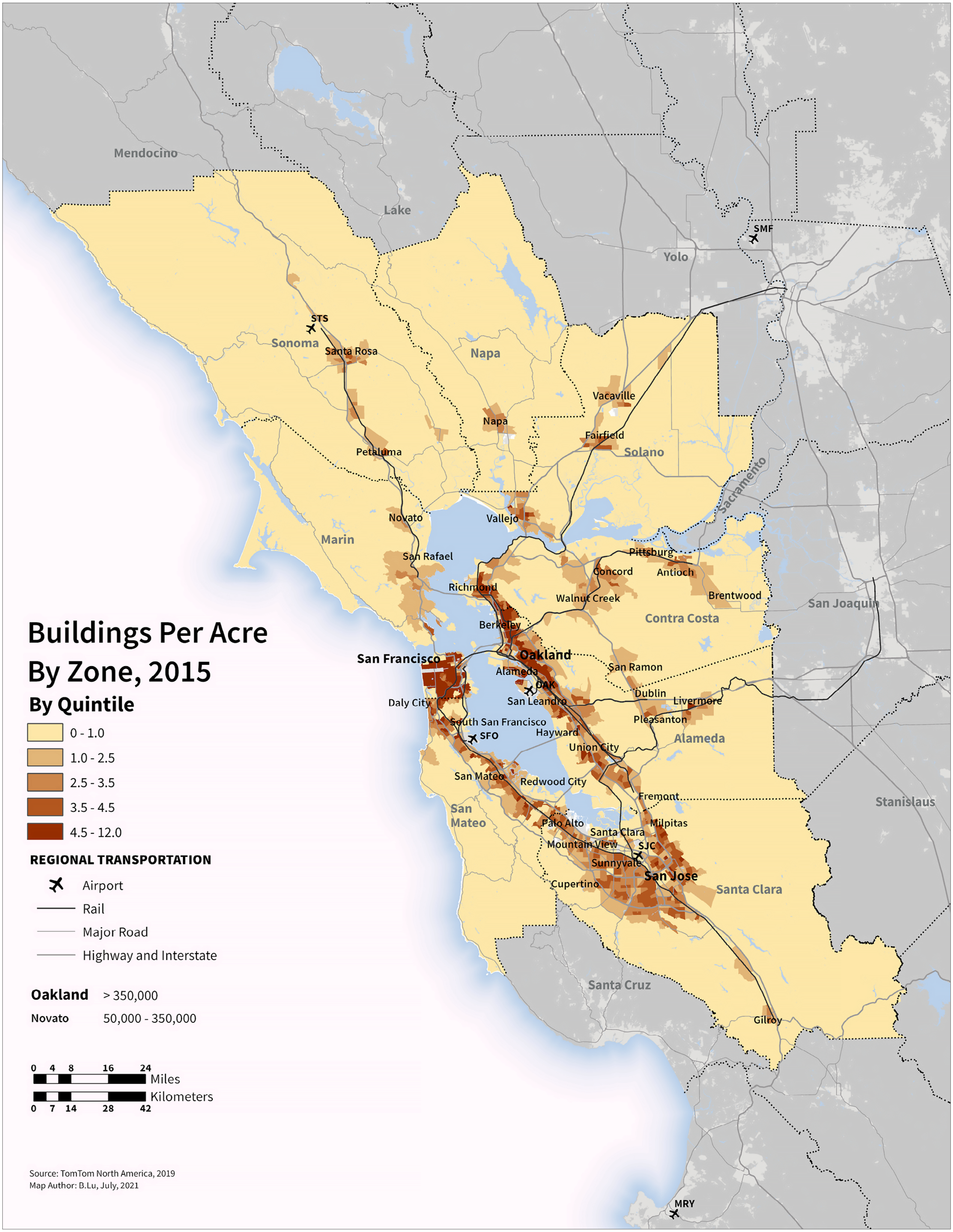


Figure 11. Buildings per acre by TAZ



Because buildings are a fundamental nexus in Bay Area UrbanSim 2 where the physical real estate market interacts with the households and employees who occupy the structures, a variety of key assumptions relate to buildings. While these assumptions greatly simplify the complexity of the region's land use market, they remain identical across EIR Alternatives allowing for consistent comparisons.

Two interrelated factors combine to determine how employees occupy buildings. First, workers in particular sectors use various types of buildings at different rates. For instance, many business service workers will use an office building, but a smaller number will occupy the same amount of light industrial space. The second step looks at the amount of square feet different types of workers use. Both use factors (types and amounts of space) were compiled on average for the entire region and assumed to be constant into the future (except for decreases in square feet per employee due to teleworking as described in the section on Strategy EN7 below). The result is an estimation of the number of jobs that could occupy a particular building, to which the model probabilistically matches employees by job sector. Household capacity, on the other hand, is directly determined by the number of residential units in a building.

Finally, Bay Area UrbanSim 2 provides flexibility in the representation of subsidized construction. Each model simulation begins with a baseline understanding of existing deed-restricted housing by zone. Various affordable housing inventory data sources and project-level data are compiled to represent the amount of deed-restricted housing which get distributed randomly within each zone. A separate component described above (the Scheduled Development Event Model) allows the construction of predetermined buildings in set future years. This list includes three types of projects: 1) buildings built between 2015 (the model forecast start year) and 2020 (the present year when the alternatives were created); 2) larger projects to be built with a mixture of public and private funding, that are currently under construction or funded; or 3) strategy representations. The same list of assumed projects for type 1 and type 2 was used for all EIR Alternatives. Type 3 projects, discussed below, were excluded from the No Project Alternative.

Development Capacity

Current zoning was obtained for all parcels in the region as a representation of the land use controls in place during the base year. Zoning or general plan data was collected for all jurisdictions through BASIS. BASIS offered cities and counties the opportunity to review the data for accuracy, which brought more transparency into the modeling process. Due to time constraints, specific plans were only collected for a limited subset of areas where such information was expected to exhibit a great deal of variation from the other planning information, and zoning and general plan data that was collected was only partially validated. To capture the latest local plans and fully incorporate local input while maintaining data accuracy, a hybrid version of current zoning was developed based on BASIS and Plan Bay Area 2040 zoning data to best represent the base year land use controls. Following the release of the Draft Blueprint, the Plan Bay Area 2050 project team conducted a series of public workshops and office hours to collect feedback from stakeholders, during which a number of jurisdictions provided additional input on BASIS development capacity data (current zoning, for example, prior to adopted strategy implementation). When accurate and appropriate, these were incorporated into the hybrid current zoning data used in Plan phase modeling. In general, constraints on new development were drawn from the information source judged most likely to represent a jurisdiction's long-term expectations for development maximums at each location.

This zoning and related information dictates the uses, residential densities, and building intensities allowed in each parcel within each jurisdiction. Adjustments to zoning were made in some locations to put protected land, government land, and transportation corridors off limits to development. Additionally, parcels containing structures built before 1930 were also deemed non-developable as a rough representation of historical protection ordinances until better data can be obtained.

Annual Business Totals

Forecasts for the region's overall rate of economic and demographic growth were developed as described in the Regional Growth Forecast section. The total number of employees by sector within the region is a result of that process and is input into Bay Area UrbanSim 2 and the resulting forecast must adhere to these totals while building and placing agents within the region. This information is used to generate new business establishments that in turn generate overall demand for commercial real estate. After new establishments are assigned locations by the Business Location Choice Model, the overall spatial distribution of employment provides input into the travel model's representation of personal travel.

Economic projections for the Bay Area are provided for the years 2015, 2020, 2025, 2035, 2040, 2045, and 2050 while intermediate years are interpolated. As seen in Table 8, the overall regional count of employment is projected to grow from around 4.0 million jobs in 2015 to almost 5.4 million jobs by 2050, or 35%. These business totals also project a changing sectoral distribution over the projection period: employment in agriculture and natural resources increases slowly over the period while the fastest growing sectors are professional services and business services.

Annual Household Totals

The total number of households by income category within the region is also forecast as part of the Regional Growth Forecast. This information is used to understand the overall demand for housing. In addition to the new households, the division of existing households into income categories is used to segment the population when considering relocation rates in the Household Transition Model. The forecasted new households and relocating households are allocated among the TAZs using the Household Location Choice Model. This spatial distribution of households is input into the Travel Model's representation of personal travel.

Working from these regional totals, Bay Area UrbanSim 2 forecasts the development of sufficient housing for all the population in the region, including all economic segments of the population. This number considers population growth, household formation, net inter-regional migration, and employment growth. The incorporation of a relaxation of local land use constraints into the regional growth forecast (as described in Findings: Regional Growth Forecast Results) results in no increase in the regional in-commute because all households supplying labor can be accommodated within the region. By forecasting the intra-regional locations for this population, Bay Area UrbanSim 2 also identifies areas within the region sufficient to house an 8-year projection of the regional housing needs under California State's Regional Housing Needs Allocation (RHNA) process.

Demographic projections for the Bay Area are provided for the years 2015, 2020, 2025, 2035, 2040, 2045, and 2050 while intermediate years are interpolated. As seen in Table 8, the overall regional count of households is projected to grow from around 2.7 million households in 2015 to over 4 million households by 2050, or 51.1%. These household totals also project a changing income distribution over the projection period: the share of households in each quartile (from lowest to highest income) is projected to shift from 26%/24%/22%/28% in 2015 to 25%/23%/19%/33% in 2050 (for the Plan and EIR Alternatives; the first two categories are slightly different in 2050 for the No Project as it lacks Strategy EC1, which envisions a statewide universal basic income).

Model Agents

Choices by key actors or agents in the region are the foundation of the Bay Area UrbanSim 2 model. The three classes of agents are households choosing places to live, business establishments choosing locations to do work, and real estate developers choosing places to build new buildings. This section discusses inputs related to each agent. Because these represent the fundamentals of the urban economy, input values are consistent across EIR Alternatives.

Households and People

Bay Area UrbanSim 2 represents each household individually. A 2015 household table with approximately 2.7 million households is synthesized for the region from Census 2010 Public Use Micro-Sample (PUMS) and Summary File 3 (SF3) tables using the PopGen population synthesizer.[18] This process creates a universe of simulated households and gives each household characteristics (such as household person count and income) so that the overall averages for those characteristics conform to the census information provided for that location. These households have a mean persons per household of 2.7, a mean number of household workers of 1.4, mean age of household head of 48.6 years, a mean household income of $81,937, and a mean number of household children of 0.5.

Establishments and Employees

Establishments are the other major class of agent in Bay Area UrbanSim 2. They represent a unique location of employment for a business. For example, a one-off barbershop is one establishment and so is one particular McDonald's restaurant location. Each establishment corresponds to a number of employees. For the Bay Area UrbanSim 2 model, the 2010 distribution of establishments and their employees are used as input. Future year projections are then made by modeling the movement of individual establishments.

The 2010 establishment database was built by combining establishment data from the Dun & Bradstreet and California Employment Development Department (EDD)[19] datasets and then transforming it to conform to base year 2015 subregional employment totals.[20] Each establishment was assigned to one of the 6 sector classes and associated with an appropriate building. Each of these sectors is modeled separately in the Employment Location Choice Model. Because no clear relocation trends were readily observable in historic data, a 1.9% chance of relocating was assumed for employment each year, regardless of sector. All employment assumptions are the same for all EIR Alternatives.

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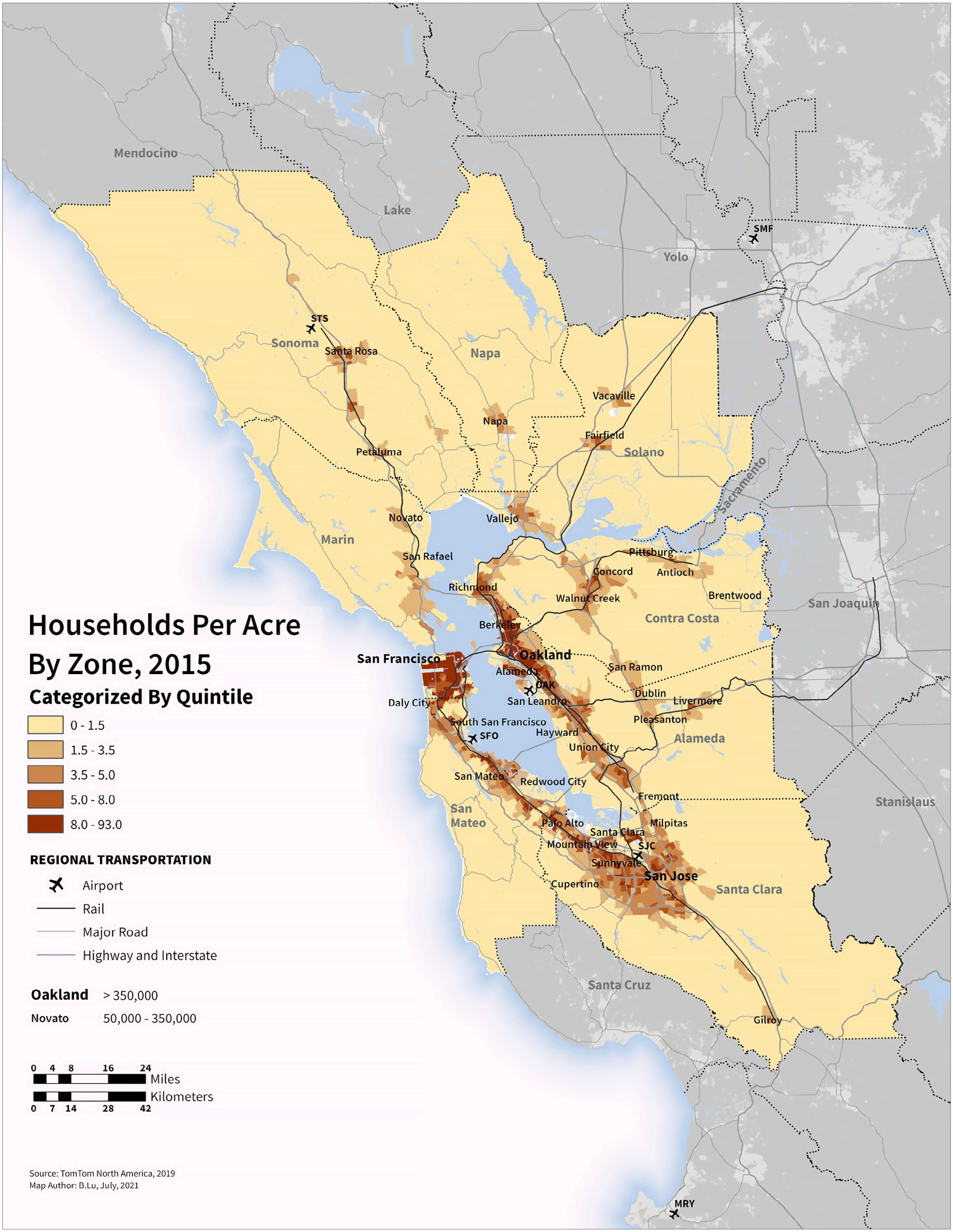
18 PopGen: http://urbanmodel.asu.edu/popgen.html.

19 California Employment Development Department (EDD): http://www.labormarketinfo.edd.ca.gov.

20 All employment databases contain slightly different counts due to different definitions, data collection strategies, and error. For more information on the regional control totals please see the section, Regional Growth Forecast.

Figure 12. Synthesized households per acre by TAZ



Real Estate Developers

The final Bay Area UrbanSim 2 agent is a special class of business: the real estate developer. Developers monitor the relationship between supply and demand for different types of buildings across the region and attempt to build new structures in locations where they can make a profit. They are driven by market forces, so assumptions related the real estate developers are identical across the four EIR Alternatives.

Bay Area UrbanSim 2 implements the Real Estate Developer Model as a stochastic, or randomly defined, pro forma model that explicitly treats these decisions the same way they are made in the real world. The pro forma combines information on costs and income over a proposed project's lifetime, allowing an assessment of overall profitability. The model examines all parcels each year and tests various project concepts allowed under the site's zoning constraints. The developer chooses the project that maximizes profit and builds the project if it is profitable. After a construction period, these new buildings are available to households and businesses for occupation.

Environmental Factors

Traditionally, Bay Area UrbanSim 2 has focused primarily on model agents and their interaction with housing and job markets in order to study these systems. However, as the impact of the natural environment becomes increasingly apparent, it has become important that the effects on these systems be considered as well.

Prior to the official kickoff of Plan Bay Area 2050, the Horizon initiative considered a wide range of external forces to stress-test strategies amidst an uncertain future. One of these forces is an earthquake, which is likely to occur in the region within the plan's 30-year time horizon. A representative earthquake along the Hayward Fault was modeled in Horizon for the first time in MTC's and ABAG's regional planning, providing an opportunity to understand the impact of this earthquake on the Bay Area's unique housing stock and the displacement of households and jobs. However, due to an inability to pinpoint the location and timing of such an earthquake, and in recognition of the significant demonstrated impacts of the shock on the forecast, the plan does not include the simulation of an earthquake in order to avoid distorting the understanding of future conditions.

The second natural force in the region that was addressed for the first time in Horizon is the rising sea level and subsequent inundation of land. This consistently encroaching force was included in Plan Bay Area 2050. As one of the first efforts to include natural hazards in regional planning, Plan Bay Area 2050 has incorporated a model to address the impacts of sea level rise in the Bay Area.

The representation of sea level rise in Bay Area UrbanSim 2 leverages detailed sea level rise projections from the Adapting to Rising Tides[21] program at the San Francisco Bay Conservation and Development Commission for inundation along the San Francisco Bay, and the National Oceanic and Atmospheric Administration for inundation along the coast. With sea level rise inundation as an input, the land use model recognizes these parcels as locations no longer viable for existing buildings and removes these buildings. Parcels that intersect with inundation were flagged for removal from the input file, and then manually reviewed to remove the designation from parcels with minimal flooding — defined to be a location where the border touches an inundation layer but does not cover a portion of the polygon. Any existing residents or jobs in these buildings are also removed and must find new locations for housing or workspaces along with the other "movers" through the location choice sub-models. After capturing the effects on existing activities, parcels subject to sea level rise are also made ineligible for new development due to the inundation, thus removing them from the total area of potential developable space to accommodate the region's population and employment.

The sea level rise sub-model in Bay Area UrbanSim 2 can represent any future inundation scenario by changing its input files. Both the progression of sea level rise inundation and the height to which the sea level will rise and cover land area are configurable, allowing staff to analyze various futures. As part of Horizon, staff studied multiple sea level rise progression scenarios to capture the widest range of possible futures. Consistent with state guidance, Plan Bay Area 2050 posits a set of progression inputs to incorporate the effects of rising tides: the plan assumes there will be 1 foot of sea level rise by 2035 and 2 feet of sea level rise by 2050.

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21 Adapting to Rising Tides: https://www.adaptingtorisingtides.org.

Baseline Policies

In addition to modeling future policy alternatives, Bay Area UrbanSim 2 includes a representation of policies which exist today and are regionally significant. Senate Bill 743 was officially adopted prior to the release of Plan Bay Area 2050 and is therefore included in all simulations; It is described further below. Other policy legislation that has been underway in California but not yet adopted may be found as a strategy in the modeling scenarios. As an example, the element of the strategy to reduce the cost of development discussed in Strategy H3: Allow a Greater Mix of Housing Densities and Types in Growth Geographies has goals similar to the reform of the California Environmental Quality Act (CEQA) development approvals process.

Senate Bill 743

California Senate Bill 743 (SB 743) is an effort to change the way the assessment of significance under CEQA is assessed. Traditionally, CEQA analysis has examined potential transportation impacts using the Level of Service (LOS) concept where impact significance occurs when highway facilities exceed a particular level of congestion. LOS assessments in dense urban areas often reveal high levels of existing congestion leading to frequent finding of significance and expensive mitigation requirements. SB 743 shifts analysis to a Vehicle Miles Traveled (VMT) method that is more likely to find transportation impacts in car-oriented suburban locations. The implementation of SB 743 is represented as having a slight (1% to 2%) increase in costs in suburban locations and a slight (again 1% to 2%) decrease in costs in urban locations with the amount of shift determined by zone level average VMT for commute trips originating in that zone.

EIR Alternatives

For the EIR analysis, Bay Area UrbanSim 2 was used to generate different alternative land use scenarios for future growth in the Bay Area. Each of these alternatives uses identical regional totals (from Table 8) representing future economic and demographic change but employs different policies constraining or promoting particular types and intensities of real estate development in particular locations.

The first alternative is called the No Project and represents the expected trajectory of the region without the implementation of the Plan or any of the alternatives. All policies in the No Project alternative are determined or extrapolated from existing base year plans and policies.

The second alternative is called the Plan, previously referred to as the Final Blueprint, and reflects the spatial distribution of future households and employment resulting from the strategies approved by the MTC and ABAG Executive Boards in fall 2020. The Plan alternative starts with base year plans and policies but modifies them as needed to represent the impacts of the strategies.

Similarly, the other two EIR Alternatives build off of the Plan while modifying existing strategies to provide a range of potential alternatives that aim to accomplish the goals pursued within the proposed plan. EIR Alternative 1 modifies strategies to minimize the development footprint by focusing on an even greater share of regional growth in low-VMT places with high-quality transit options. To a greater degree than the Plan, EIR Alternative 2 promotes housing growth in locations that are jobs-rich and/or are high-resource. Strategies in this alternative are designed to address the regional challenges of displacement and gentrification.

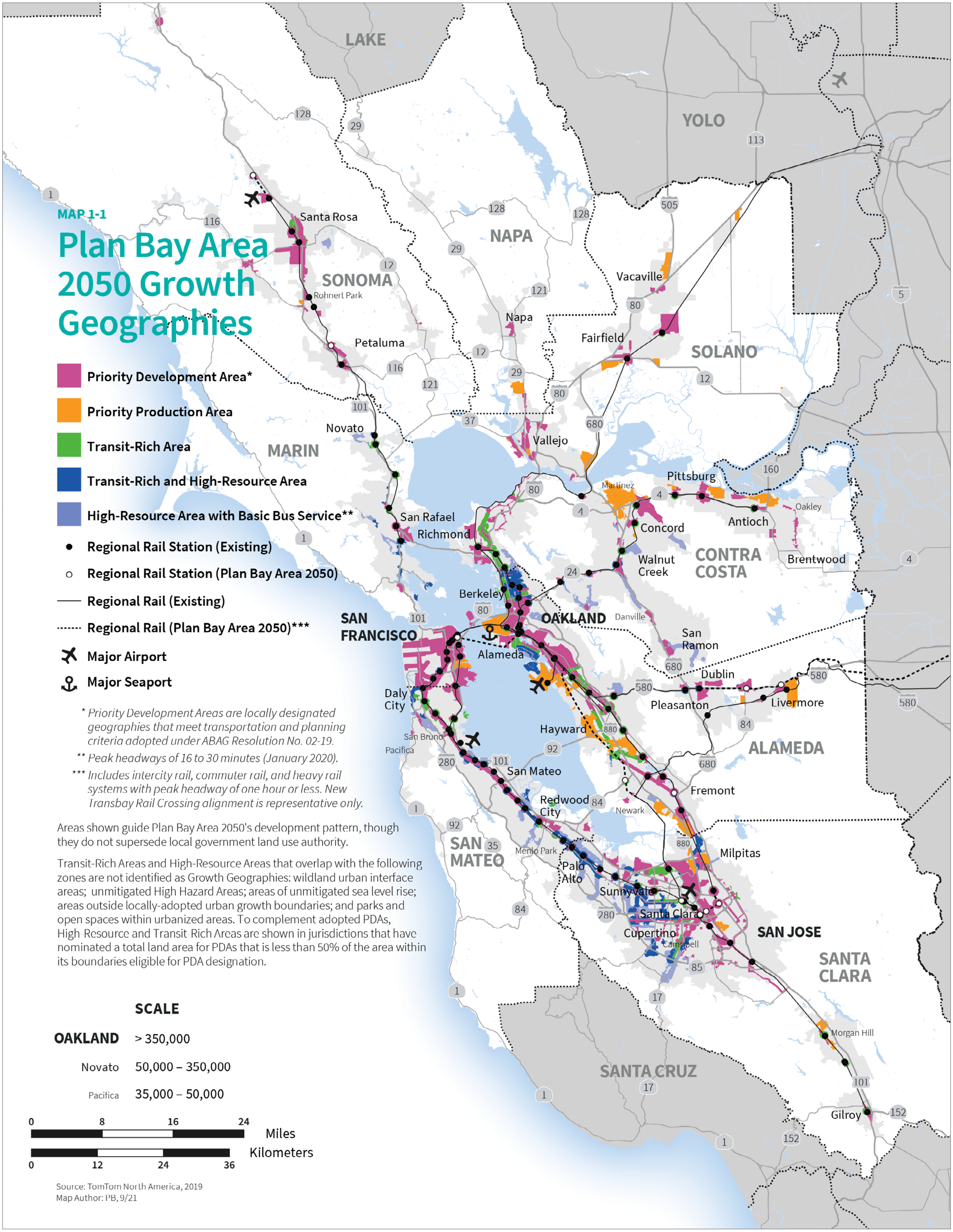
Growth Geography Framework

To advance the various goals of the EIR Alternatives, a spatial framework was established to carry out strategies and evaluate the outcomes of such strategies. The Growth Geographies are places identified for housing and/or job growth either by local jurisdictions or because of their proximity to transit or access to opportunity. For modeling purposes, a series of specific Growth Geographies were established to further define the overall definition of Growth Geographies (GG) adopted by the Commission and Executive Board in September 2020 (mapped in Figure 13). They have been identified spatially according to the following rules and used as the building blocks for several strategies.

Table 11. Growth Geography definitions

GEOGRAPHY NAME			DEFINITION
Growth Geography (GG)			In all local jurisdictions, these areas included locally designated Priority Development Areas (PDAs) and Priority Production Areas (PPAs), as well as Transit-Rich Areas (TRAs) served by BART or Caltrain Baby Bullet routes. In cities that have nominated less than 50% of the land within their boundaries eligible for designation as a PDA, these areas also include: all TRAs not included in a PDA including both High-Resource Areas (HRAs) and places outside HRAs; and HRAs that are outside of a TRA but within ¼ mile of a bus stop with 16- to 30-minute peak period headways
Priority Development Areas (PDAs)			Locally identified places for housing and job growth
Transit-Rich Areas (TRAs)			These are areas within ½ mile of transit, further distinguished by the quality of transit:
	TRA1		Rail transit stop served by at least 3 BART routes or 1 BART route and 1 Caltrain Baby Bullet route
	TRA2		Rail transit stop that does not meet the TRA1 definition and is served by BART or Caltrain; light rail stop; or bus stop served by a bus rapid transit route with peak headways of 1-9 minutes. Some alternatives divide this category into three sub-categories to more precisely apply the strategies:
		TRA2a	Typical BART station or Baby Bullet Caltrain station
		TRA2b	Typical Caltrain station or high-frequency light rail station with dedicated right-of-way (e.g., Muni Metro Castro Station)
		TRA2c	High-frequency light rail (e.g., Muni Metro J-Church surface stations); moderate-frequency light rail station with dedicated right-of-way (e.g., VTA North 1st corridor); BRT stop or station
	TRA3		Rail transit stop that does not meet the TRA1 or TRA2 definition; ferry terminal; or bus stop served by at least one route with a 1-15 minute peak headway
High-Resource Areas (HRAs)			Census Tracts designated “High or “Highest” Resource by the California Departments of Housing and Community Development and Finance, clipped to urban footprint
Priority Production Areas (PPAs)			Locally identified places for middle-wage job growth in industries like manufacturing, logistics, or other trades; must be zoned for industrial use or have a predominately industrial use

Figure 13. Plan Bay Area 2050 Growth Geographies



Policymakers can apply incentives or disincentives — financial or regulatory — in an effort to influence land use. These are referred to as “housing, economy and environment strategies” or “land use strategies” for short. Differences in the land use strategy inputs are the fundamental means of representing the different EIR Alternatives. The strategies represent actions that MTC, ABAG, or partner agencies such as cities and counties could take or seek legislation to allow. These input assumptions vary between alternatives and when combined with the more fundamental Model Agents described above, produce model outputs.

The land use strategies described in this section are applied in the same fashion to all alternatives except the No Project alternative, unless otherwise noted. The variation across alternatives derives mostly from the way these strategies are implemented within the region, or not implemented at all, and will be discussed in relation to each strategy.

Apart from the strategies modeled explicitly in Bay Area UrbanSim 2, economic and transportation strategies act on the land use pattern and enter through the interactions between models. Region-level economic strategies influence the level of demand for housing and job space as well as the characteristics of this demand that may be shaped by factors such as the income levels of households. Transportation strategies influence the accessibility of different locations in the region, which can increase the feasibility of housing or commercial development in these locations in the land use model.

Strategy H1 | Further Strengthen Renter Protections Beyond State Law

Strengthening renter protections across the region builds upon tenant protection laws and limits rent increases, and is thus modeled as a change in the behavior of renter households. The policy is represented as a slowing of the relocation rate of renters and increased stability. Based on PUMS 2013-2017 data, it is estimated that renter households have an 80% likelihood of relocating within five years. This is used to set the probability a modeled household will move and re-enter the search for housing. Renter protections are modeled as a 15% decrease in the rate of relocation for low-income households. The resulting relocation probability is therefore 67% within each five-year model time step. Consequently, low-income renter households remain in their homes longer than other household groups as the region continues to grow and the land use pattern evolves.

Strategy H2 | Preserve Existing Affordable Housing

To maintain the existing affordable housing in the region, funding is used over the plan period to preserve units as permanently deed-restricted housing. In the No Project alternative, only preservation funding from existing federal, state, and local sources is available. Funding levels remain relatively similar to the baseline year and are continued through the plan horizon year to preserve units. This results in 110,050 additional deed-restricted units by 2050: 22,600 in Alameda, 15,000 in Contra Costa, 3,150 in Marin, 1,650 in Napa, 14,950 in San Francisco, 13,500 in San Mateo, 28,150 in Santa Clara, 5,150 in Solano, and 5,900 in Sonoma. In all other alternatives, Bay Area UrbanSim 2 applies affordable housing funds by randomly selecting housing units for preservation. Once an affordable housing unit becomes preserved, the subsidized unit is then prioritized for low-income households in the model.

Housing in the region is selected for preservation and allocated funding if it is located within one of the three following areas: Transit-Rich Areas (TRAs), the Displacement Risk (DR) geographies,[22] or the general Growth Geography (GG) areas. The funding is further specified by county, based on the base year number of low-income households in these geographies and the number of low-income households otherwise expected to leave these areas without the preservation of housing. First, an equal or greater number of units than the number of low-income households in a given county in 2010 were preserved in the “DR+TRA” and “TRA only” geographies. Next, where a net loss in low-income households was projected in Draft Blueprint modeling results between 2010 and 2050 in “DR” geographies,

22 Displacement Risk geographies are derived from the UC Berkeley Urban Displacement Project (https://www.urbandisplacement.org/map/sf). They are within census tracts designated: “At Risk of Gentrification or Displacement (Low Income)”, “Ongoing Gentrification / Displacement of Low Income Households (Low Income)”, “At Risk of Exclusion (Moderate to High Income)”, and “Ongoing Exclusion / Displacement of Low Income Households (Moderate to High Income)”.

an equal or greater number of units than the number of low-income households in 2010 was preserved in “DR only” geographies. In counties that had a reduction in the percentage of low-income households between 2010 and 2050, and a deficit in low-income units remained, additional units were preserved to fill in the gap. Lastly, any remaining low-income units to meet the regional target were added to “GG” geographies in each county, proportional to its 2010 share of the region’s low-income households. Table 12 details the resulting targets for the number of units to preserve in Bay Area UrbanSim 2 within the Growth Geography combinations in each county.

Table 12. Preservation of affordable housing by county and Growth Geography

	TOTAL PRESERVED UNITS TARGET								
	Alameda	Contra Costa	Marin	Napa	San Francisco	San Mateo	Santa Clara	Solano	Sonoma
DR+TRA	27,500	8,500	5,000	0	27,500	7,500	38,500	500	5,000
DR only	0	0	6,000	0	500	0	0	0	0
TRA only	99,000	12,500	5,000	500	93,000	17,000	64,000	3,000	5,000
GG (any)	2,500	1,000	12,000	0	54,000	41,500	2,000	500	500

Bay Area UrbanSim 2 uses four household income categories, described in Table 7. To give low-income households priority for these units, an initial household location choice model runs which only places low-income households into deed-restricted units. Afterwards, a general household location choice model runs to place remaining households. Once a unit becomes preserved as affordable, low-income households either continue to occupy these units or relocate into them based on historical rates. The time it may take for a low-income household, or a new low-income household, to occupy a preserved unit is reflective of the transaction costs of moving.

Strategy H3 | Allow a Greater Mix of Housing Densities and Types in Growth Geographies

All alternatives start with the basic zoning classification established as the development capacity inputs. For most alternatives, zoning modifications are made for various subsets of parcels in the region. Zoning modifications act on two components: the set of building types allowed on a parcel and the maximum dwelling units per acre (if the modification is not already permitted under the local zoning). Zoning schemas are guided by the regional Growth Geographies which have been used in combination to create the detailed zoning schema. The No Project alternative assumes current land use regulations captured in the base zoning do not change between now and 2050. Further, the No Project alternative assumes that trends in the expansion of the region’s urban limits (as discussed below under Maintain Urban Growth Boundaries) continue to accommodate some of the region’s growth.

In the Plan, zoning is modified to broaden allowable building types and increase development density in Transit-Rich Areas (TRAs) and High-Resource Areas (HRAs) to encourage growth near transit and in high-resource neighborhoods. Table 13 provides the detail on the zoning modifications in the Plan. Zoning differs between parcels containing single family dwelling (SFD) units and parcels not containing SFD units to account for local context.

Table 13. Residential zoning modifications for the Plan

PLAN			
Zoning Alternative Geography		Maximum Dwelling Units per Acre Applied	
	Broadened Allowable Building Type	Parcels not occupied by Single Family Dwelling (SFD) Units	Parcels occupied by Single Family Dwelling (SFD) Units
GG + TRA1 + HRA	Multifamily Dwelling (MFD)	200	50
GG + TRA1 + nonHRA	MFD	150	50
GG + TRA2 + HRA	MFD	100	50
GG + TRA2 + nonHRA	MFD	75	35
GG + TRA3 + HRA	MFD	50	50
GG + TRA3 + nonHRA	MFD	35	35
GG + nonTRA + HRA	MFD	35	35
GG + nonTRA + nonHRA	n/a	25	25

EIR Alternative 1 increases zoning intensity in all TRAs to a greater amount than the proposed Plan alternative to create a more transit-supportive land use pattern. This alternative further refines the TRA categories to create a schema that enables more development around the regional transportation infrastructure providing the most service. The TRA categories used in EIR Alternative 1 are defined within the Growth Geography framework (Table 11), and the modifications to residential development capacity are detailed in Table 14.

Table 14. Residential zoning modifications for EIR Alternative 1

EIR ALTERNATIVE 1		
Zoning Alternative Geography	**Broadened Allowable Building Type**	**Maximum Dwelling Units per Acre Applied**
GG + TRA1	MFD	300
GG + TRA2a	MFD	300
GG + TRA2b	MFD	250
GG + TRA2c	MFD	250
GG + TRA3	MFD	100

EIR Alternative 2 broadens use types and increases residential densities in a selection of HRAs and TRAs in specific jurisdictions to encourage low-income housing in jobs-rich communities. Compared to the Plan, this alternative lowers upzoning for TRA1 and TRA2 to allow more growth in a greater array of jurisdictions. Additionally, within jobs-rich and high resource cities (defined below), as well as within their surrounding jurisdictions, upzoning in transit-rich and Growth Geography areas is higher where these overlap with high-resource areas. This contributes to more potential growth in HRAs to achieve a better jobs-housing balance. Importantly, there is a limitation on upzoning any parcels with multi-family development in Equity Priority Community (EPC) geographies[23], which is included to mitigate potential displacement impacts. The TRA categories used in EIR Alternative 2 are defined within the Growth Geography framework (Table 11), and the modifications to residential development capacity are detailed in Table 15.

Jobs-rich and high-resource cities are those with a job-housing ratio greater than 1.75 in addition to being identified as exclusionary in the final draft 2023-2031 RHNA allocation (via "equity adjustment" calculation). These include St. Helena, Pleasanton, Menlo Park, Palo Alto, Cupertino, and Milpitas. Adjacent cities are defined as jurisdictions within a five-mile of radius of these cities, which include Atherton, Belmont, Calistoga, Campbell, Dublin, East Palo Alto, Fremont, Hayward, Livermore, Los Altos, Los Altos Hills, Los Gatos, Monte Sereno, Mountain View, Newark, Portola Valley, Redwood City, San Carlos, San José, San Ramon, Santa Clara, Saratoga, Sunnyvale, Union City, and Woodside.

23 More information on the Equity Priority Communities framework can be found here: https://github.com/BayAreaMetro/Spatial-Analysis-Mapping-Projects/tree/master/Project-Documentation/Equity-Priority-Communities .

Table 15. Residential zoning modifications for EIR Alternative 2

EIR ALTERNATIVE 2			
Zoning Alternative Geography		Maximum Dwelling Units per Acre Applied	
	Broadened Allowable Building Type	Parcels in Job-Rich and High-Resource Cities and Adjacent Cities	Parcels in All Other Jurisdictions
GG + TRA1 + HRA	MFD	125	125
GG + TRA1 + nonHRA	MFD	125	125
GG + TRA2 + HRA	MFD	100	75
GG + TRA2 + nonHRA	MFD	55	55
GG + TRA3 + HRA	MFD	75	50
GG + TRA3 + nonHRA	MFD	35	35
GG + nonTRA + HRA	MFD	75	50
GG + nonTRA + nonHRA	n/a	35	35

Figure 16 provides an overview of zoning modifications within the Urban Growth Boundaries of incorporated areas across all alternatives.

Figure 14. Plan Bay Area 2050 Growth Geographies: Transit-Rich Area (TRA) details

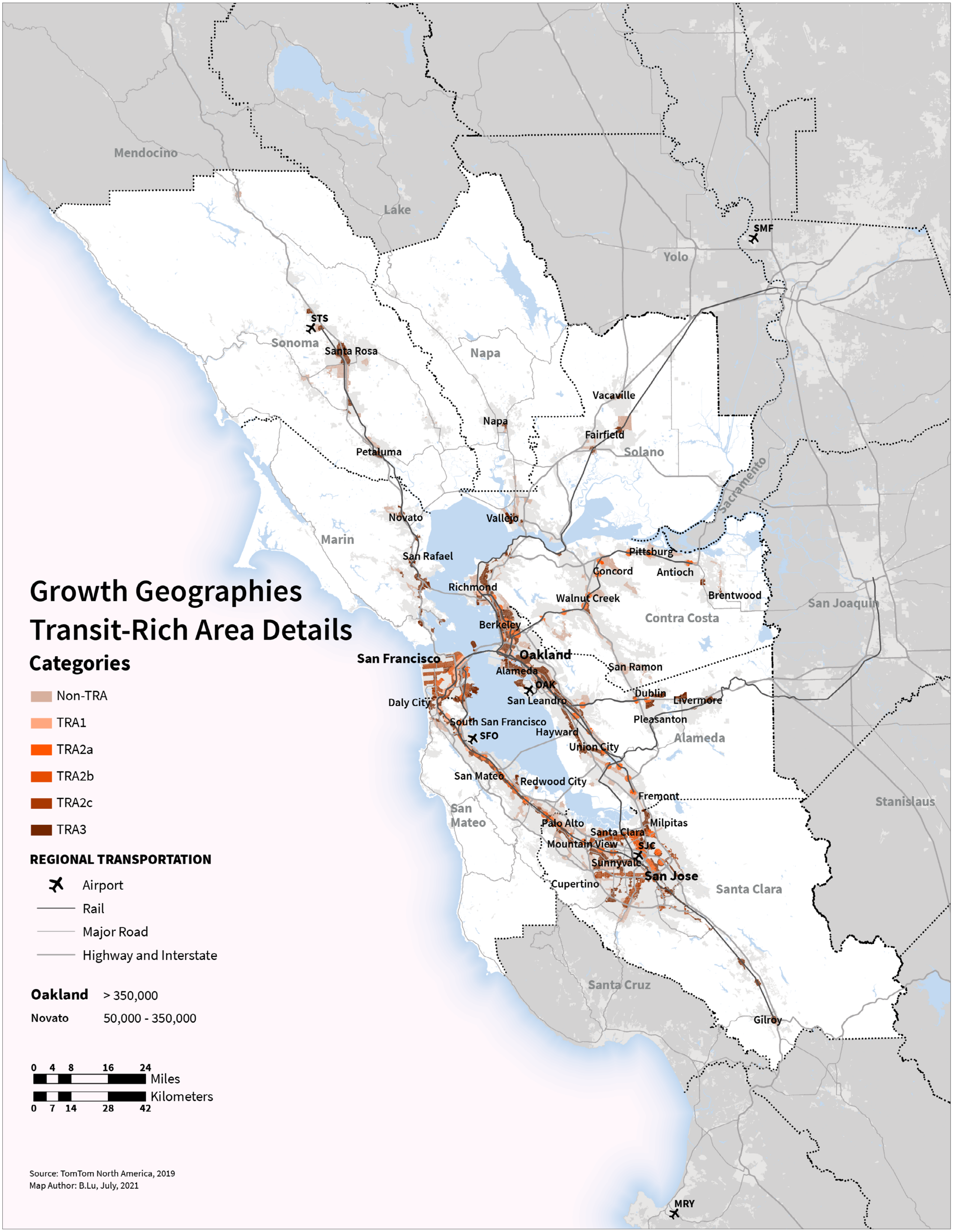


Figure 15. Plan Bay Area 2050 Growth Geographies: High-Resource Area (HRA) details

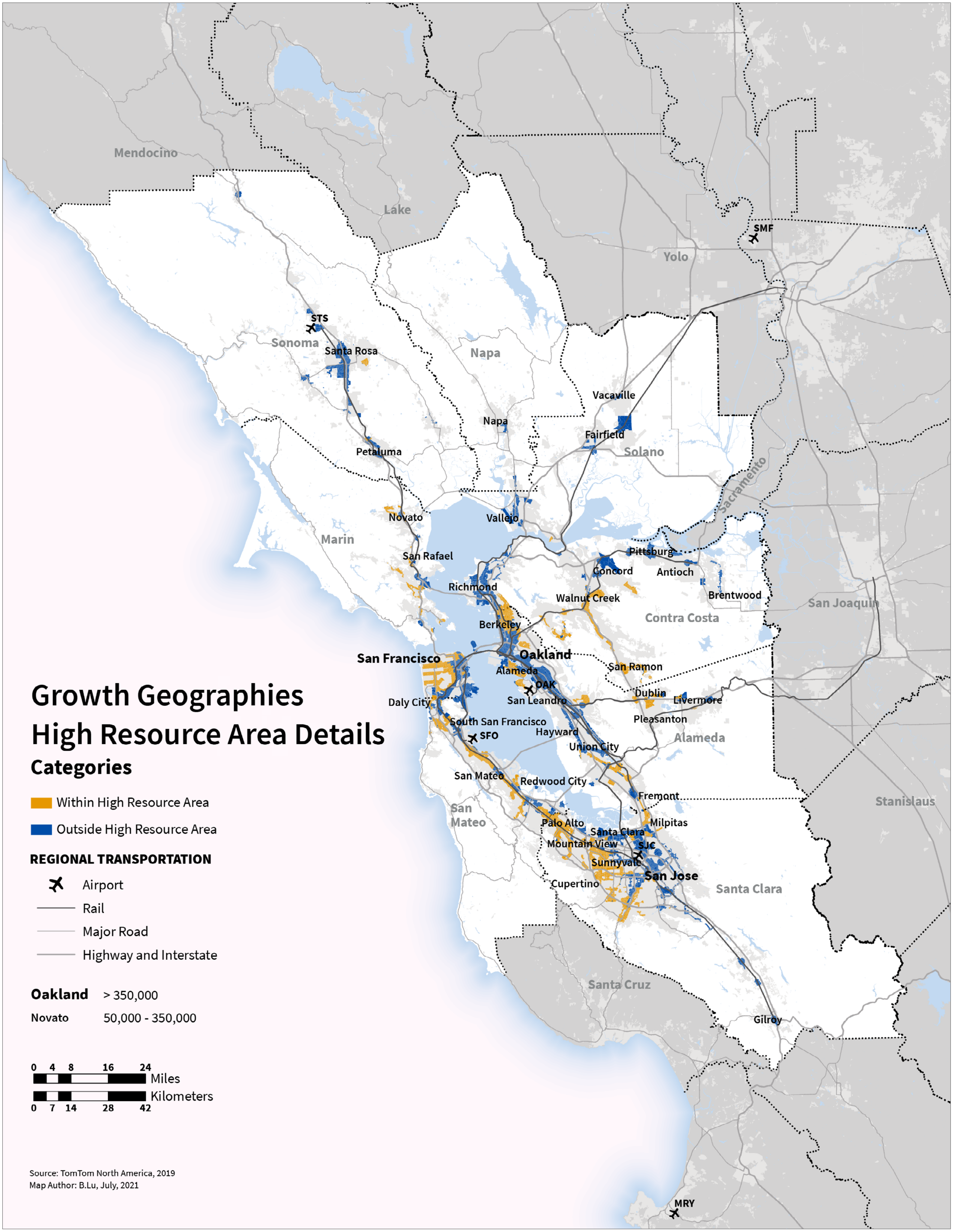
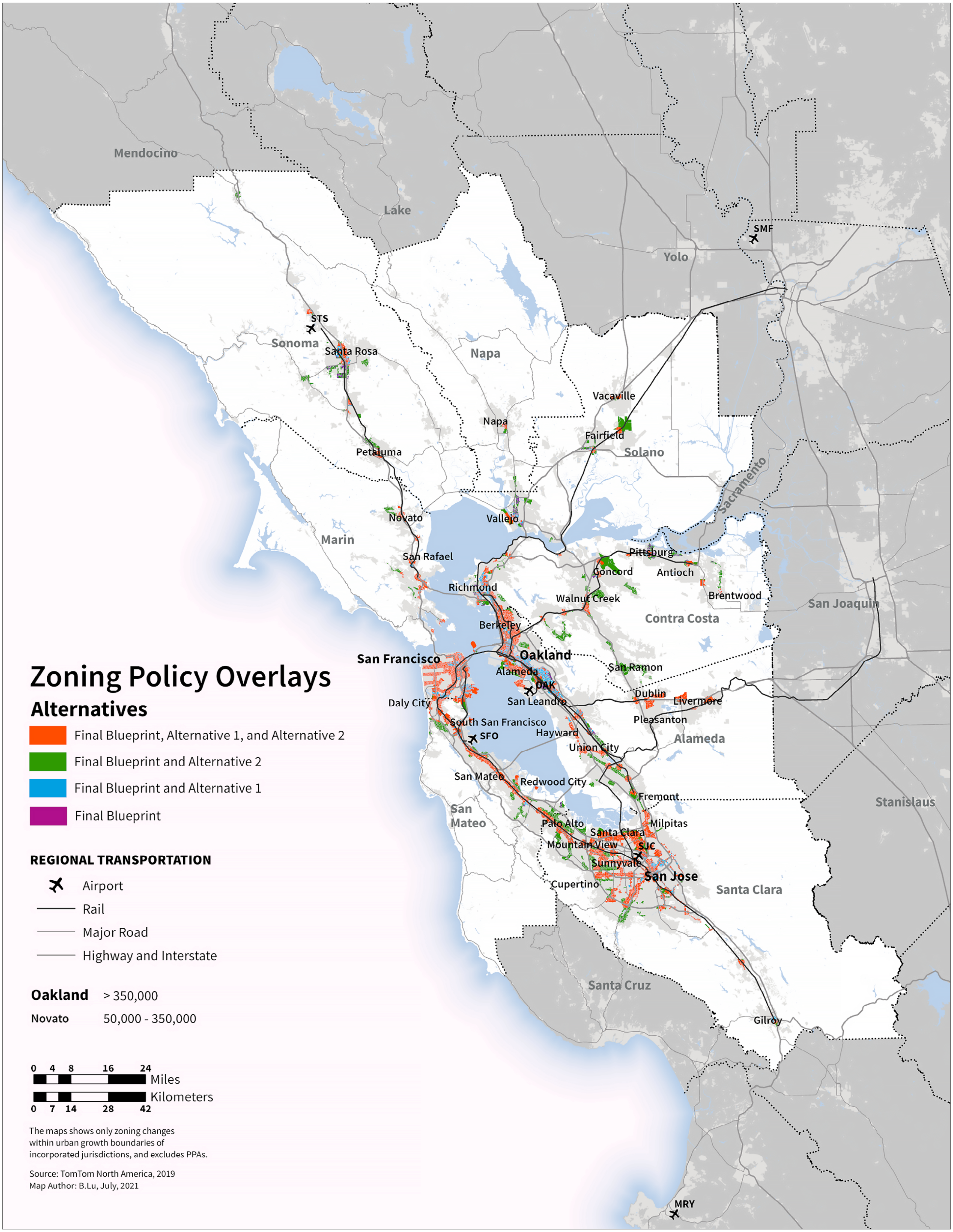


Figure 16. Zoning policy overlays across alternatives



To encourage growth in areas with access to the region's best public transit, schools, and community services, the plan also seeks to remove barriers to housing development in these locations. To do so, certain costs associated with housing development are limited, such as project review times and parking requirements. This is represented in the land use model as an increase in profit for the market-rate developer, thus increasing the feasibility of housing projects. The profit increases are applied using three tiers, determined by their levels of access to transit and resources. The profit increase levels associated with the savings are 1.3%, 1.9% and 2.5%. These amounts are based on estimates of development fees as a share of total housing costs and reflect the impact of reducing a specific share of these development costs.[24]

Strategy H4 | Build Adequate Affordable Housing to Ensure Homes for All

In addition to the preservation of affordable housing in the region, the alternatives also allow for the production of affordable housing to help meet the needs of low-income households. In the No Project alternative, only production funding from existing federal, state, and local sources is available. Funding levels remain similar to the baseline year and are continued through the plan horizon year to create deed-restricted units. This results in 117,000 additional deed-restricted units by 2050: 24,100 in Alameda, 15,900 in Contra Costa, 3,300 in Marin, 1,800 in Napa, 15,900 in San Francisco, 14,300 in San Mateo, 29,900 in Santa Clara, 5,400 in Solano, and 6,400 in Sonoma.

In all other alternatives, funding is used in the land use model to produce new deed-restricted housing over the forecast period. The funding is directed within the region according to the alternative's goals: the Plan uses production money only within the Growth Geographies, EIR Alternative 1 uses money in Transit-Rich Areas within the Growth Geographies, and EIR Alternative 2 splits funding evenly between High-Resource Areas and non-High-Resource Areas within the Growth Geographies. In the model, this production funding is made available for deed-restricted housing in individual counties based upon its share of the region's population, and existing city-and county-generated funding sources. Table 16 details the allocation of available funding by county.

Table 16. Production funding targets for affordable housing by county and Growth Geography: total production funding (millions of $)

	PLAN	EIR ALTERNATIVE 1	EIR ALTERNATIVE 2	
County	GG	GG + TRA	GG + HRA	GG + non-HRA
Alameda	4,000	4,000	2,000	2,000
Contra Costa	2,500	2,500	1,250	1,250
Marin	520	520	260	260
Napa	300	300	150	150
San Francisco	3,000	3,000	1,500	1,500
San Mateo	2,500	2,500	1,250	1,250
Santa Clara	5,000	5,000	2,500	2,500
Solano	850	850	425	425

24 12% is used as a proxy for development fees as a share of total development costs, based upon It All Adds Up: The Cost of Housing Development Fees in Seven California Cities (2018), Terner Center, which found fees in California range between 6%-18% of total development costs.

To build these units, the land use model identifies residential development projects that are close to being financially feasible under market conditions. Subsidizing these projects fills the "feasibility gap" and the financial need of projects is sorted to maximize the number of projects that can become feasible with the given funding. Building these projects creates deed-restricted units, which are only available to low-income households. This is complemented by the direct allocation of additional deed-restricted units through the Transform Aging Malls and Office Parks into Neighborhoods and the Accelerate Reuse of Public and Community-Owned Land for Mixed-Income Housing and Essential Services strategies.

Strategy H5 | Integrate Affordable Housing into All Major Housing Projects

An inclusionary zoning policy is included in Bay Area UrbanSim 2 as a requirement that new residential construction include a set percentage of units that are available exclusively to low-income residents. A default set of inclusionary zoning percentages capture the jurisdictional requirements in place today and these levels remain in place for the No Project. The default percentages came from multiple data sources, including research conducted by MTC and other entities[25], and local zoning ordinance or municipal code of Bay Area jurisdictions. The other EIR Alternatives vary these levels to tailor the requirements by location. Any new residential building must provide the percentage of affordable units required in each of the Growth Geographies, shown in Table 17.

Table 17. Minimum percent of affordable housing units in new development

	INCLUSIONARY PERCENTAGE
GG + TRA1/TRA2/TRA3 + HRA	20%
GG + TRA1/TRA2	15%
GG + HRA	15%
Other Areas	10%

Bay Area UrbanSim 2 reflects the requirement by altering the feasibility of building a new residential project. If a project remains profitable, the affordable units will be constructed. This process captures the challenges of building projects that have lower revenue but the same costs, with some otherwise feasible projects shifting to other locations. Like other affordable units, when projects are built with inclusionary units, only households in the lowest income quantile are prioritized to occupy them.

25 Data compiled by Association of Bay Area Governments in February 2017: https://mtc.maps.arcgis.com/home/item.html?id=4b-77830210d14982a3256fd7b67f68ee; Inclusionary Housing Map & Program Database maintained by InclusionaryHousing.org, a project of Grounded Solutions Network developed with support from the National Housing Conference and the Lincoln Institute for Land Policy: https://inclusionaryhousing.org/map/.

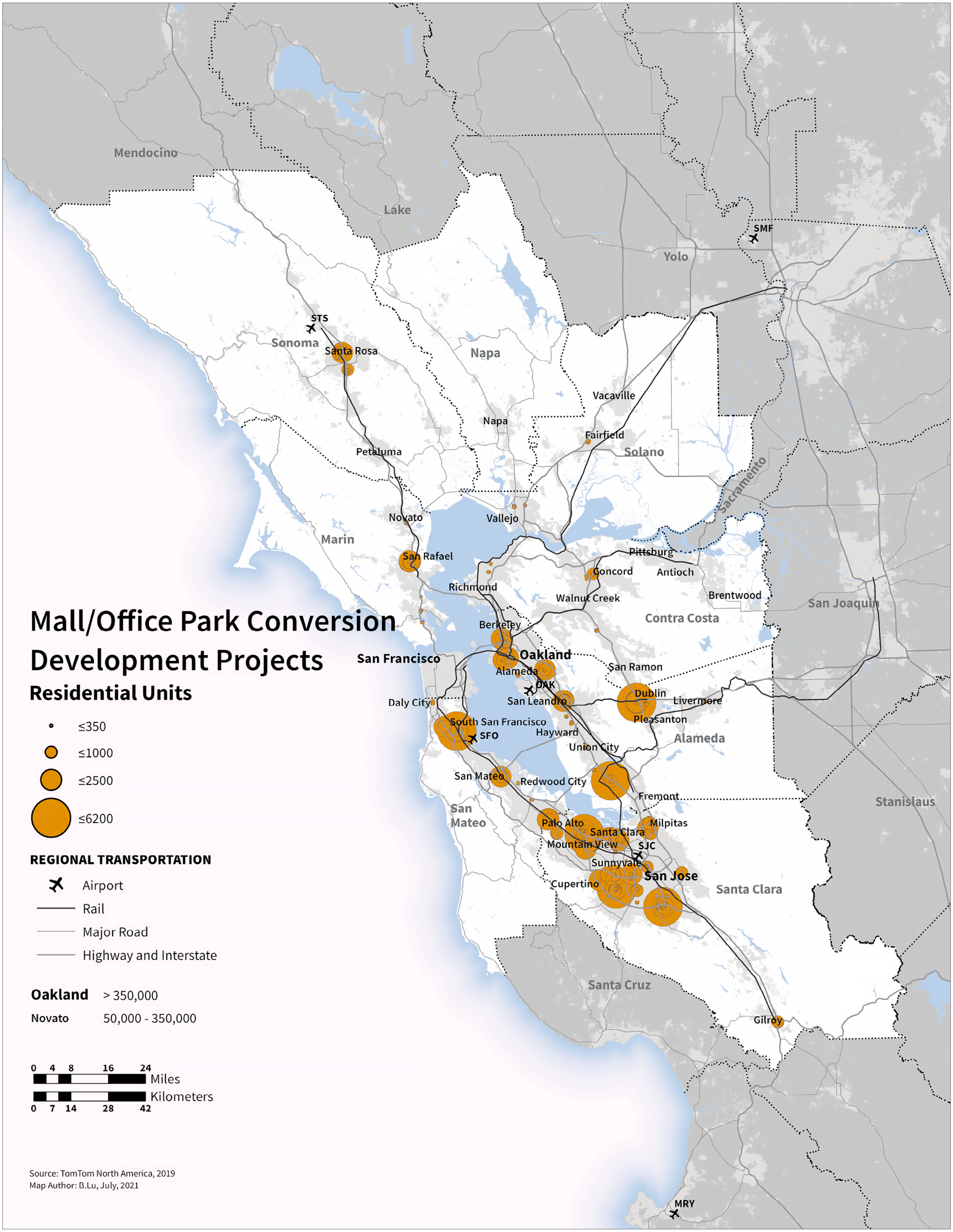
Strategy H6 | Transform Aging Malls and Office Parks into Neighborhoods

The transformation of aging malls and office parks promotes the reuse of land for critical housing, bringing new uses to these sites as neighborhoods with housing at all income levels as well as local and regional services. These projects are implemented through the Scheduled Development Events Model, where staff generate representative new projects that would comprise these sites and the model constructs them.

Malls and office parks in the region were analyzed to understand their likelihood of transitioning to new uses by assessing the age and value of existing buildings and the potential profitability under a new use. To support neighborhood-scale developments, only sites larger than 20 acres were assessed. Sites also needed to be located within a Growth Geography and required access to either transit, social resources, or both. In the Plan, the resulting set of malls and office parks were converted into new neighborhoods. In EIR Alternative 1, only projects within TRAs were built. In EIR Alternative 2, all projects within HRAs were constructed, while projects outside of HRAs were de-prioritized by random selection to achieve the focus of 50% of housing production in HRAs.

To support affordable housing production and capture the value created by rezoning particularly large sites, redeveloped malls and office parks with more than 1,000 new units are assumed to set aside adequate land for affordable housing at a ratio of 0.2:1 (or 20% of the project's housing units, in line with the upper bound of Strategy H4: Build Adequate Affordable Housing to Ensure Homes for All). Deed-restricted units above and beyond the inclusionary requirement contributed to this strategy as well. These are mall and office park transformation projects with 1,000+ dwelling units, which have a "set aside" for additional affordable housing on top of inclusionary requirements.

Figure 17. Mall/office park conversion development projects

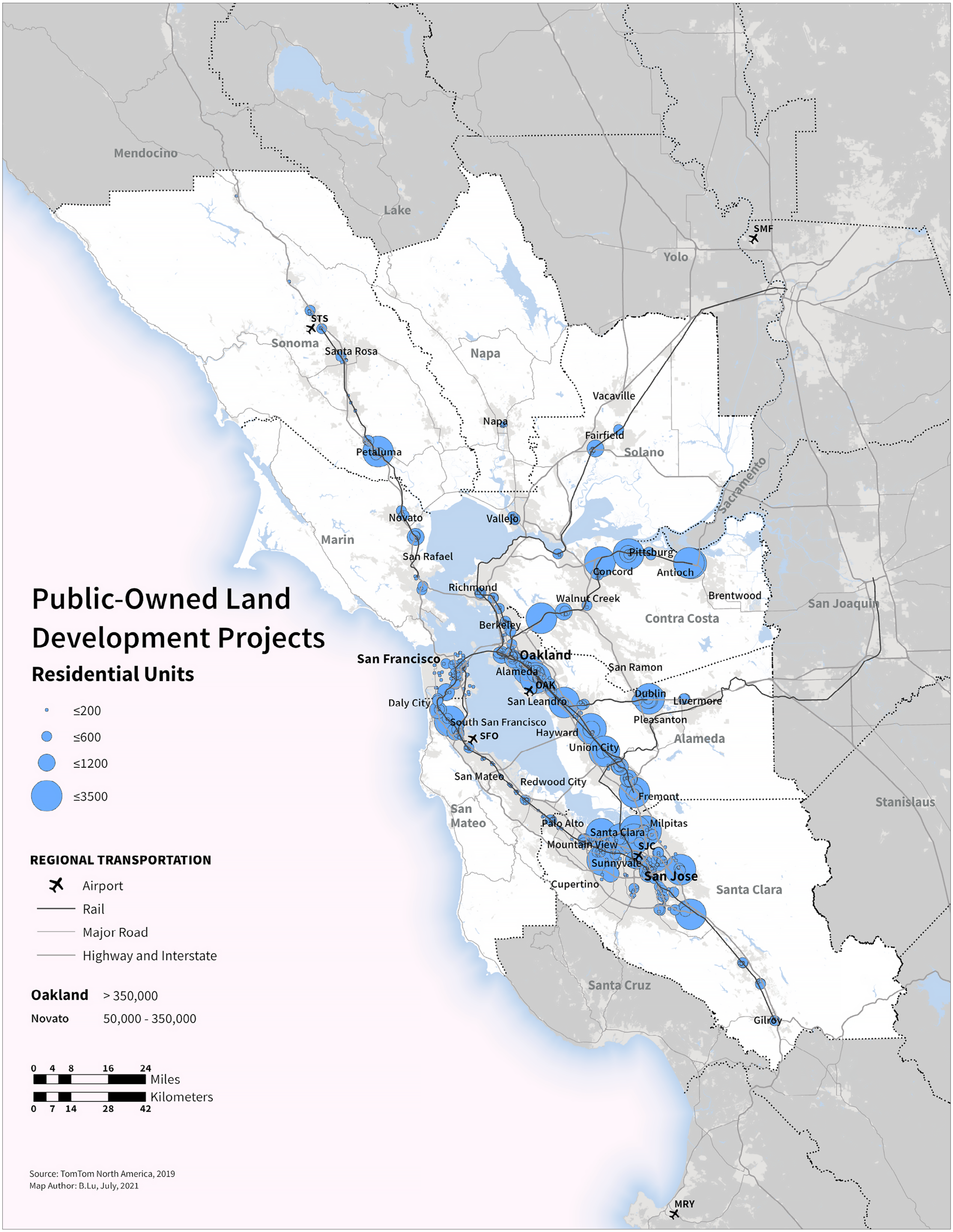


Strategy H8 | Accelerate Reuse of Public and Community-Owned Land for Mixed-Income Housing and Essential Services

Another strategy that makes effective use of land for housing is the development of public and community-owned land. This is accomplished first by identifying sites in the region owned by public agencies, community land trusts, and other non-profit landowners. By opening these sites for development, affordable housing and local services can be constructed. In the same way that mall and office park transformations are added to the development landscape, these projects are developed through the Scheduled Development Events Model. These developments were primarily 100% affordable housing projects, with some mixed-used projects to add commercial space for services. Staff generated projects to fit the building envelope of the parcels while considering appropriate scale for these sites.

All publicly owned sites identified for reuse were prioritized for development in upcoming and future years based upon size, transit proximity, and existing land use, if any. The first built were those on land owned by transit agencies within Transit-Rich Areas. These were followed by vacant sites in Transit-Rich Areas that are less than 10 acres, sites in Transit-Rich Areas that are less than 10 acres and occupied by buildings constructed before 1980, sites in Transit-Rich Areas that are larger than 10 acres and were assessed for viability of their current use, and finally other remaining sites. In the Plan, the full final set of public and community-owned lands were developed. In EIR Alternative 1, only projects in the Growth Geography area and within TRAs were built. In EIR Alternative 2, all projects within HRAs were constructed, while not all projects outside of HRAs were converted.

Figure 18. Public-owned land development projects



Strategy EC2 | Expand Job Training and Incubator Programs

Business incubators are used as an economic development catalyst for the creation of new small businesses and are designed to support training for high-growth, in-demand occupations. This strategy provides funding support for incubators and is modeled as the development of new incubator spaces. Incubators are co-located in select Priority Production Areas (PPAs) specifically in housing-rich locations to encourage job opportunities. Twenty-five jurisdictions nominated 34 PPAs around the region, which were adopted by MTC and ABAG in early 2020. Of these, PPAs with a jobs-housing ratio of less than 1.4 were assumed to receive incubator funding. The following PPAs fall under this criterion:

1. Bayside Industrial PPA
2. Pacific Commons PPA
3. Hayward PPA
4. Oakland Airport PPA
5. San Leandro PPA
6. Union City PPA
7. Northern Waterfront Industrial Corridor
8. Northern Concord PPA
9. Western Concord PPA
10. Oakley Employment Area
11. Pittsburg Northern Waterfront
12. Pacheco Manufacturing Zone
13. Baypoint Industrial Sector
14. American Canyon PPA
15. Northern Palmetto PPA
16. Morgan Hill PPA
17. Monterey Business Corridor
18. Benicia Industrial PPA
19. Dixon Northeast Quadrant
20. Fairfield PPA
21. Rio Vista PPA
22. Suisun City Gentry
23. Vacaville Industrial PPA
24. South Vallejo PPA
25. Cotati PPA

In Bay Area UrbanSim 2, these incubator spaces are represented by adding 450,000 square feet of industrial development within each PPA through the Scheduled Development Events model. Over time, the Employment Location Choice model may choose to locate jobs in these incubator buildings.

Strategy EC4 | Allow Greater Commercial Densities in Growth Geographies

As with residential zoning, commercial land use is treated in each of the alternatives to guide the region's employment growth. The zoning schemas are applied at the parcel level, allowing new building types on a parcel and/or changes to the Floor Area Ratio (FAR) (where not already permitted by local zoning). The commercial land use modifications in the alternatives are guided by the Growth Geographies previously defined in this report. In many situations, increased commercial zoning on a parcel coincides with zoning for denser residential development, meaning that these uses compete with one another, and also work to create mixed-use environments.

The No Project alternative maintains the existing commercial land use allowable intensities present in the base year model inputs. In the Plan, zoning is modified to increase development density in Transit-Rich Areas (TRAs) to encourage transit-supported commercial growth. In EIR Alternative 1, commercial development intensity is also increased in Transit-Rich Areas, with somewhat higher maximum allowed Floor Area Ratios than those in the Plan. In this alternative, TRAs in cities with three or more rail lines with frequent service are given even slightly higher FARs to encourage employment growth in locations with the most robust transit service. San Francisco, Oakland, Daly City, and San Leandro meet the requirements of having three or more rail lines as well as having peak service headways of five minutes or fewer. Since EIR Alternative 2 has a focus on creating housing opportunity in High-Resource Areas, commercial land use was not modified, and the base year zoning is maintained.

Table 18. Commercial density modifications across the alternatives

PLAN			
Zoning Alternative Geography	Broadened Allowable Building Type	Maximum Floor Area Ratio (FAR) Applied	
		Parcels not occupied by Single Family Dwelling (SFD) Units	Parcels occupied by Single Family Dwelling (SFD) Units
GG + TRA1	n/a	9	3
EIR ALTERNATIVE 1			
Zoning Alternative Geography	Broadened Allowable Building Type	Maximum Floor Area Ratio (FAR) Applied	
GG + TRA1 + three or more frequent rail lines	n/a	15	
GG + TRA1	n/a	12	
EIR ALTERNATIVE 2			
Zoning Alternative Geography	Broadened Allowable Building Type	Maximum Floor Area Ratio (FAR) Applied	
All Geographies	n/a	Local Zoning	

Strategy EC5 | Provide Incentives to Employers to Shift Jobs to Housing-Rich Areas Well-Served by Transit

To improve jobs-housing balance, this strategy uses building subsidies to encourage employers to locate in housing-rich areas near existing transit. These subsidies are used to support new office development in the land use model in a way similar to subsidizing housing: the land use model identifies office development projects that are close to being financially feasible under market conditions. Subsidizing these projects fills the “feasibility gap” and allows for office development projects that would not otherwise be built.

To meet the locational objectives of the strategy, the subsidy is only applied in select housing-rich cities, focusing on those with regional rail services (Table 19). These were the 11 cities with frequent rail services and four cities with other regional rail services such as SMART. The first group of cities has job-housing ratios lower than 1.2 at both the county and the jurisdiction levels in the base year; cities in the second group are either city centers or are linked to the New Transbay Rail Crossing. The total amount of $10 billion in subsidy is split between the two groups, with $9.5 billion going to the first group and $500 million going to the second group.

Table 19. Office development subsidies to improve jobs-housing balance

COUNTY	JURISDICTION	QUALIFICATIONS FOR SUBSIDY	SUBSIDY AMOUNT (2020$)
Alameda	Dublin	• 2015 job-housing ratios lower than 1.2 in both the county and the jurisdiction • Frequent rail services	864,000,000
Alameda	Fremont		864,000,000
Alameda	Oakland		864,000,000
Alameda	San Leandro		864,000,000
Alameda	Union City		864,000,000
Contra Costa	Antioch		864,000,000
Contra Costa	Concord		864,000,000
Contra Costa	El Cerrito		864,000,000
Contra Costa	Lafayette		864,000,000
Contra Costa	Pittsburg		864,000,000
Contra Costa	Richmond		864,000,000
Marin	San Rafael	• Other regional rail services • City center	125,000,000
Solano	Fairfield	• Other regional rail services • City center • Connected to New Transbay Rail Crossing	125,000,000
Solano	Vacaville	• Other regional rail services • Connected to New Transbay Rail Crossing	125,000,000
Sonoma	Santa Rosa	• Other regional rail services • City center	125,000,000

Strategy EC6 | Retain and Invest in Key Industrial Lands

This strategy focuses on industrial lands in order support and grow production, advanced manufacturing, distribution, and related businesses and middle-wage jobs. Priority Production Areas (PPAs) served as a basis for identifying the region's industrial land assets. Industrial zoning is maintained in the PPAs that intersect with the Growth Geographies through the allowed building types in the land use model. The zoning was modified to allow industrial use without competition from multifamily use. Development capacity in these PPAs was also increased to a maximum Floor Area Ratio (FAR) of 2 in this schema to accommodate new industrial development.

In addition, a subsidy of $4 billion was applied to allocate funding to jurisdictions with PPAs that are within the Urban Growth Boundaries. The funding is used to subsidize industrial development projects and to promote employment growth, especially in places with otherwise limited forecasted growth. To accomplish this, staff first looked at the BAUS2 model run results without integrating the industrial development subsidy and grouped the jurisdictions with PPAs into two categories based on their allocation of jobs in the manufacturing and wholesale sector as well as the transportation and utilities sector. The first group is jurisdictions with job growth in the these two sectors of over 800 jobs. These jurisdictions receive 15% of the total amount of subsidy, divided equally, and include Benicia, Fremont, Hayward, Livermore, Morgan Hill, Pacifica, San José, and Vacaville. The second group received the remaining 85%, divided equally, and includes American Canyon, Antioch, Concord, Cotati, Dixon, Fairfield, Milpitas, Oakland, Oakley, Pittsburg, Rio Vista, San Francisco, San Leandro, unincorporated Contra Costa County, Union City, and Vallejo.

Staff then converted the PPA funding for each jurisdiction into non-residential development projects using a cost factor of $50 per square foot. These projects were added to PPA parcels in their jurisdictions as scheduled development events, spread equally over 2025, 2030, 2035, 2040, 2045 and 2050. The model then constructed these projects in their respective future years.

Strategy EC7 | Assess Transportation Impact Fees on New Office Developments

This strategy is a fee on new commercial development that reflects transportation impacts associated with such development. The development fee focuses primarily on new commercial spaces anticipated to have high employment-related or residence-related vehicle miles traveled (VMT).

This strategy is used in EIR Alternative 1 to incentivize development inside low-VMT job centers. The fees are applied to new office development, set on a cost per square foot basis. The fees are further specified at the county level. The transportation impact of new development is based on the average VMT per worker by county in 2020, which is based on TAZ-level VMT data from Plan Bay Area 2040. The rationale for the different fees by county is to right-size the fee based on average county VMT. Table 20 below shows the resulting fees by VMT level.

Table 20. New office development fees (dollars per square foot)

	VERY HIGH VMT TAZ	HIGH VMT TAZ	MEDIUM-HIGH VMT TAZ	MEDIUM VMT TAZ
Alameda	40	30	15	4
Contra Costa	40	30	10	n/a
Marin	40	30	8	n/a
Napa	40	30	10	n/a
San Francisco	60	40	20	10
San Mateo	40	30	10	n/a
Santa Clara	40	30	10	4
Solano	40	30	10	n/a
Sonoma	40	30	10	n/a

This strategy is not included in any other EIR Alternatives, including the Plan.

Strategy EC8 | Implement Office Development Caps in Job-Rich Cities

Office Development Caps is a strategy applied in EIR Alternative 2 to help redistribute job growth in the region and to maximize the land availability for housing in job-rich cities. The job-housing ratio is used as a metric for understanding which cities have the greatest imbalance in their number of jobs versus housing units. In cities with at least two jobs per housing unit, or a job-housing ratio of 2 or greater, office development caps were applied in the land use model. Restricting new office development in these locations redistributes the modeled regional job demand. Jobs may move to existing vacant office space or into new office space built by the developer model in feasible locations.

The following cities had jobs-housing ratios of 2 or greater[26]:

- Emeryville
- Brisbane
- Menlo Park
- Santa Clara
- Mountain View
- South San Francisco
- Milpitas
- Burlingame
- Palo Alto
- Colma
- Cupertino

This strategy is not included in any other EIR Alternatives, including the Plan.

26 2016 jobs-housing ratios based on US Census 5-year data.

Strategy EN1 | Adapt to Sea Level Rise

As mentioned in the section on Environmental Factors, Plan Bay Area 2050 assumes a future with one foot of sea level rise by 2035 and two feet of sea level rise by 2050. To reduce the impact of associated inundation, the Plan, EIR Alternative 1 and EIR Alternative 2 include efforts to mitigate sea level rise by addressing adaptation needs. Protective measures are funded in most locations that are permanently inundated. Equity Priority Communities and areas with high benefit and low cost are prioritized for protection. In the No Project alternative, mitigation is much more limited; only committed mitigation project locations are protected from sea level rise. The committed mitigation projects are: San Francisco Airport Shoreline Protection Program, Foster City Levee Project, South Bay Shoreline Project, and Oakland Airport Sea Level Rise Adaptation.

In the land use model, protected areas become spared from inundation. This is done by altering the input files that specify inundated parcels. When a parcel is removed from the inundation set, households and jobs are no longer displaced from that parcel, and the land is available for new development that can accommodate the region's growth.

Strategy EN4 | Maintain Urban Growth Boundaries

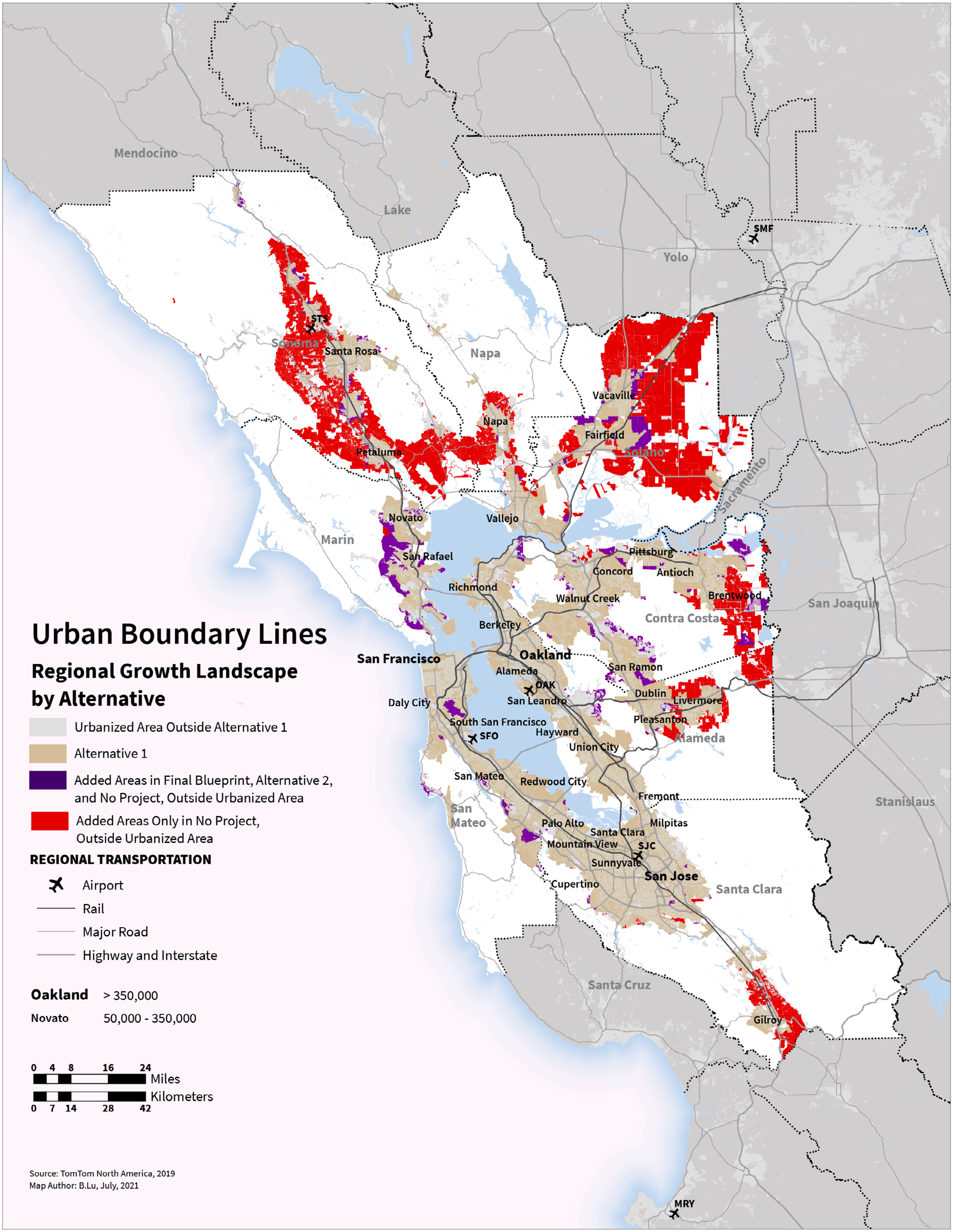
For the purpose of building EIR Alternatives, a consistent set of Urban Boundary Lines surrounding each city was established. These are meant to function like Urban Growth Boundaries in the EIR Alternatives. In some cases, the Urban Boundary Lines are drawn from true urban growth boundaries or urban service areas. In other cases, existing city boundaries are used to establish the Urban Boundary Line for EIR analysis.

The Urban Boundary Lines are treated in two different ways across EIR Alternatives. In the No Project alternative, they are assumed to be weakly enforced, meaning that suburban growth will be allowed to spill out past them. In the Plan and in EIR Alternative 2, the enforcement is assumed to be strict, meaning suburban growth is not allowed beyond them. In EIR Alternative 1, the boundaries limiting outward expansion are assumed to be the current city limits in all cases. Currently unincorporated land and any additional land within the Urban Boundary Line in each alternative is zoned to allow typical single-family development if not already permitted.

In the No Project alternative, the amount and location of growth beyond the Urban Boundary Lines must be determined. In the forecast, this can be thought of as land that is expected to become incorporated during the next three decades, either through city expansion or the formation of new cities. This is done by changing the zoning to allow suburban densities in particular locations and letting Bay Area UrbanSim 2 decide how much growth to place in those locations based on its representation of the regional land market. A total of 697 square miles of land was updated to allow typical suburban densities based the ratio of new incorporated land to population growth during the past three decades. Land was identified using a simple rule-based model that prioritized parcels that were near divided highways and had low slope within a five-mile radius (i.e., areas posited as most likely to incorporate). All land in this area was considered available in the base year.

The differential enforcement of Urban Boundary Lines across the alternatives results in different amounts of land being open for development by Bay Area UrbanSim 2's Real Estate Development sub-model. As seen in Figure 19, these potential "expansion areas" emphasize different degrees of regional compactness.

Figure 19. Urban boundary lines across alternatives



Strategy EN7 | Expand Commute Trip Reduction Programs at Major Employers

Modeling the strategy to expand commute trip reduction programs is primarily carried out through Travel Model 1.5 (see Strategy EN7: Expand Commute Trip Reduction Programs at Major Employers in that section). In the travel model, fewer trips are taken by auto and are substituted with an increase in the rate of telecommuting. Within Bay Area UrbanSim 2, the reduced number of employees going to their office on a given day results in an increase in building space efficiency. This strategy was represented in the same manner for the Plan and Alternatives 1 and 2. The resulting shift in building capacity was estimated by combining two factors at the super district zone level:

The share of workers likely to telework on a given day. Recent data on current workers was analyzed across all combinations of industry and occupation to understand the general compatibility of particular jobs (and their set of task requirements) for telework. These numbers were adjusted upward within Travel Model 1.5 to reflect the impacts of this strategy. Sub-areas of the Bay Area with larger shares of workers who were judged more likely to telework saw a larger change in this factor. By 2050 the superdistrict share of teleworkers ranged from 9% in Northwestern San Francisco to 25.5%. The largest increases in the share of teleworkers were in the Tri-Valley and the portion of the Inner East Bay from San Leandro to Hayward.

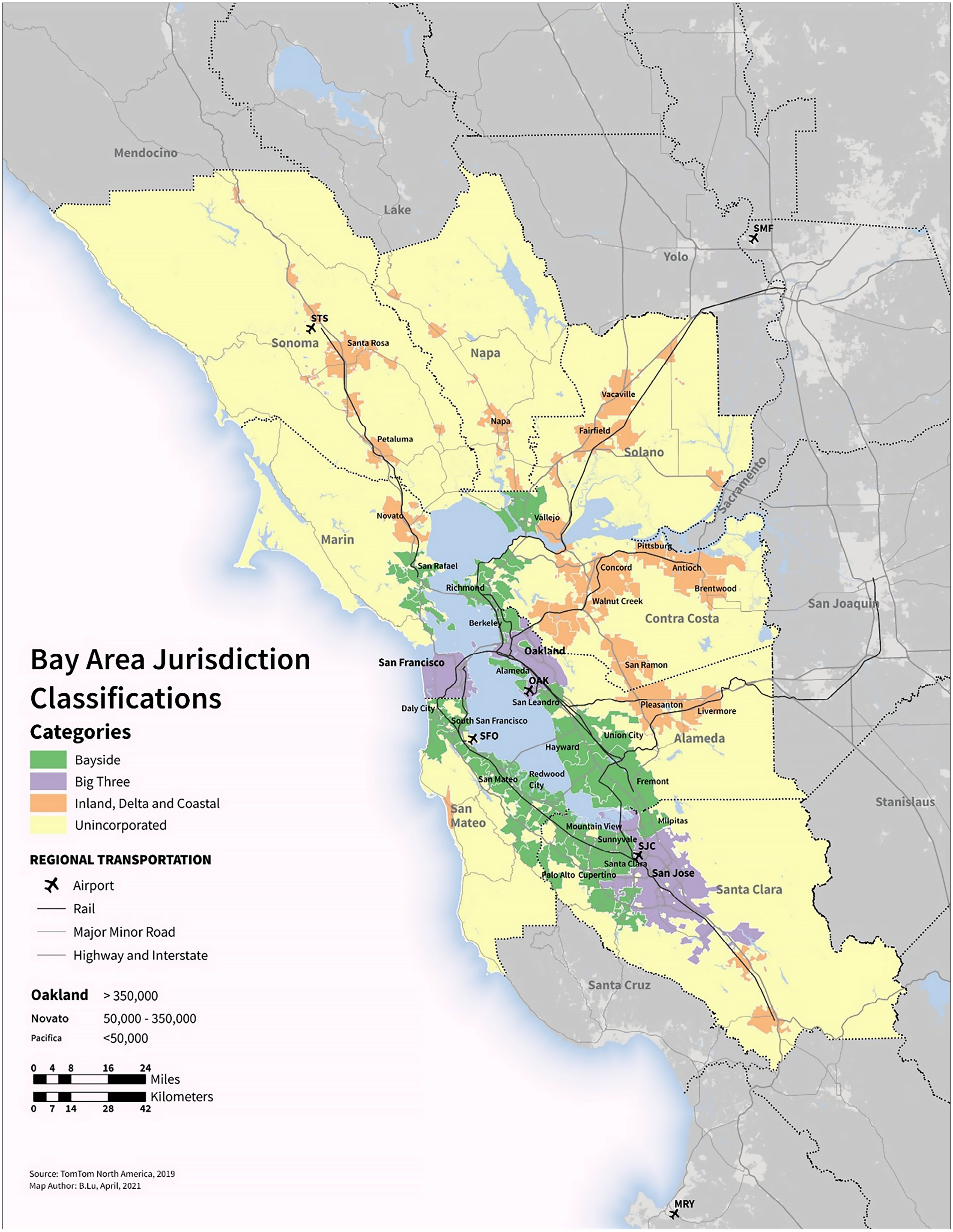
The "hoteling rate" at which it was assumed these workers could share their office workspaces. As a larger share of workers telework some days but continue to work in person on other days, firms are likely to re-arrange their offices by increasing the number of shared workspaces, often referred to as "hoteling". While some anecdotal data exists on this shift historically, it is difficult to forecast the degree to which offices will reduce their average square feet of rented space per employee. For the forecast, it is assumed that the hoteling rate (as applied to the share of workers that are teleworking) will range from 1/3 shared space in more expensive locations to no sharing in less expensive areas.

This strategy is then represented by applying each super district's hoteling rate to the share of workers expected to telework in a future year. This resulted in a reduced demand for commercial square feet of 7% by 2050 with the largest reductions occurring in San José and Oakland and very little expected change in most the North Bay. Overall, this tended to increase the tendency for employment growth in existing major job centers such as the San Francisco Central Business District and Silicon Valley because a greater number of employees can be accommodated by the large amount of existing space.

Findings

Selected land use model results are summarized and discussed here. The output presented is partial and intended to give a general sense of expected behavioral change across the alternatives and through the projection years. Emphasis is given to results that 1) influence the Travel Model, 2) affect Plan Bay Area 2050 results, and 3) provide a context for understanding the regional development change predicted by each alternative.

Figure 20. Map of Bay Area jurisdiction classification categories



Regional Land Use Outcomes

The share of regional population and employment growth provides a simple means of comparing the land use model outcomes for the four EIR Alternatives. For comparison, Figure 20 assigns the region's jurisdictions into four large categories: the Big Three Cities (San José, San Francisco, and Oakland); Bayside Cities; Inland, Delta and Coastal Cities; and Unincorporated Areas.

Table 21 shows the share of regional household growth for each alternative through 2050. Table 22 shows the share of regional employment growth for each alternative through 2050.

Table 21. Share of regional household growth across alternatives

AREA	2050 ALTERNATIVE			
	No Project	Plan	EIR Alternative 1	EIR Alternative 2
Big Three Cities	41%	43%	44%	37%
Bayside Cities	24%	34%	40%	40%
Inland, Delta and Coastal Cities	21%	18%	15%	18%
Unincorporated	15%	5%	1%	4%

NOTE: results may not total to 100% because of rounding.

Table 22. Share of regional employment across alternatives

AREA	2050 ALTERNATIVE			
	No Project	Plan	EIR Alternative 1	EIR Alternative 2
Big Three Cities	44%	39%	37%	47%
Bayside Cities	40%	45%	44%	36%
Inland, Delta and Coastal Cities	13%	13%	16%	14%
Unincorporated	3%	3%	4%	3%

Small Zone Outcomes

While the regional distribution of households and employment will influence travel behavior, a more micro-level understanding of growth is also fundamental in understanding each alternative's ability to achieve plan goals. As described above, the three small zones employed in the plan process are Priority Development Areas (PDAs), Transit-Rich Areas (TRAs), and High-Resource Areas (HRAs). Figure 13, above, shows these zones as well as additional Growth Geographies and areas of overlap. Table 23 provides the share of regional household growth in PDAs, TRAs, and HRAs for the alternatives through year 2050. Table 24 shows similar information for employment growth shares.

Table 23. Small zone share of household growth across alternatives

AREA	2050 ALTERNATIVES			
	No Project	Plan	EIR Alternative 1	EIR Alternative 2
PDAs	51%	72%	76%	66%
TRAs	63%	82%	91%	79%
HRAs	24%	28%	29%	39%

NOTE: results may not total to 100% because of rounding and/or overlapping zone definitions.

Table 24. Small zone share of employment growth across alternatives

AREA	2050 ALTERNATIVES			
	No Project	Plan	EIR Alternative 1	EIR Alternative 2
PDAs	51%	48%	50%	51%
TRAs	65%	63%	63%	63%
HRAs	18%	14%	15%	5%

NOTE: results may not total to 100% because of rounding and/or overlapping zone definitions.

Jobs-Housing Balance Outcomes

The jobs-housing balance is an ongoing topic of interest in the Bay Area, given wide variation between job-rich and housing-rich counties. The regionwide jobs-to-housing ratio decreases from 1.50 in 2015 to 1.34 by 2050, reflecting a higher ratio of housing to job production to accommodate pent-up demand for housing. Overall, the Plan results in counties converging toward the regional jobs-housing ratio of 1.34. The North Bay and East Bay subareas, while still below the regional average, are both moving closer to regional average. Similarly, the traditional jobs-rich Peninsula and South Bay subareas remain jobs-rich, but are moving closer to the regional jobs-housing ratio.

Table 25. Jobs-housing balance across alternatives

		2050 ALTERNATIVES			
COUNTY	2015	No Project	Plan	EIR Alternative 1	EIR Alternative 2
Regionwide	1.50	1.34	0.1.34	1.34	1.34
Alameda	1.58	1.40	1.40	1.37	1.43
Contra Costa	1.06	0.74	0.97	1.17	1.00
Marin	1.25	0.90	0.80	0.84	0.88
Napa	1.42	1.51	1.56	1.56	1.61
San Francisco	1.86	1.91	1.59	1.44	1.94
San Mateo	1.47	1.26	1.28	1.15	1.32
Santa Clara	1.78	1.56	1.51	1.52	1.32
Solano	0.93	0.95	1.14	1.30	1.12
Sonoma	1.18	1.21	1.14	1.14	1.12

Housing Affordability Outcomes

Housing affordability is another issue of great regional concern. As seen in Housing affordability is another issue of great regional concern. As seen in Table 26, households spend much more on housing than typically considered healthy (i.e., not more than 30% of income). Across all income categories, households have been spending 33% of income on housing while for the lowest quartile of households this figure has been around 68% in recent years. All alternatives contain higher levels of market rate construction in future years and this additional housing is forecast to decrease costs by the amount seen in the No Project results. The other alternatives also add a large amount of low-income, deed-restricted housing where subsidies cover costs above 30% of household income. These alternatives see a great deal of reduction in housing costs., households spend much more on housing than typically considered healthy (i.e., not more than 30% of income). Across all income categories, households have been spending 33% of income on housing while for the lowest quartile of households this figure has been around 68% in recent years. All alternatives contain higher levels of market rate construction in future years and this additional housing is forecast to decrease costs by the amount seen in the No Project results. The other alternatives also add a large amount of low-income, deed-restricted housing where subsidies cover costs above 30% of household income. These alternatives see a great deal of reduction in housing costs.

Table 26. Share of income spent on housing across alternatives

	ALTERNATIVE 2050				
	2015	No Project	Plan	EIR Alternative 1	EIR Alternative 2
Low-Income Households	68%	44%	29%	29%	29%
All Households	33%	25%	21%	21%	21%

Travel Modeling Suite

MTC and ABAG use an analytical tool known as a travel model (also known as a travel demand model or travel forecasting model) to first describe the reaction of travelers to transportation projects and policies and then to quantify the impact of cumulative individual decisions on the Bay Area's transportation networks and environment. MTC's and ABAG's travel modeling suite is comprised of three main analytical tools: a population synthesizer, a travel model, and a vehicle emission model. Each tool is described in turn below. While the travel model is able to represent most of the strategies and policy interventions in the plan, some elements of transportation strategies are not captured, and the calculations performed to analyze these policies are described in the section on Off-Model Calculations.

Population Synthesizer

MTC and ABAG's travel model is an agent-based simulation. The "agents" in this case are individual households, comprised of the people who form each household. In this way, the travel model attempts to simulate the behavior of the individuals and the households who carry out their daily activities in a setting described by the input land development patterns and input transportation projects and policies. To use this type of simulation, each agent must be characterized in a fair amount of detail.

Software programs that create lists of households and persons for travel model simulations are known as population synthesizers. For Plan Bay Area 2050, MTC and ABAG began using the population synthesizer, PopulationSim.[27] The population synthesizer attempts to sample households described in the 2007-2011 Census Public Micro-sample (PUMS) data in such a way that when looking at the population along specific dimensions spatially (at a level of detail below which the PUMS data is reported), the aggregate sums more or less match those predicted by other Census summary tables (when synthesizing historical populations) or the land use projections made by the Land Use Model (when forecasting populations). For example, if Bay Area UrbanSim 2 forecasts that 60 households containing 100 workers and 45 children will live in spatial unit X in the year 2035, the population synthesizer will locate 60 PUMS households in spatial unit X and will select households in such a way that, when summing across households, the number of workers is close to 100 and the number of children is close to 45.

The population synthesizer "controls" (i.e., minimizes the discrepancy between the synthetic population results and the historical Census results or the land use forecasts) at the travel analysis zone (TAZ) along the following dimensions:

1. Number of total households (individuals living in non-institutionalized group quarters, e.g. college dorms, are counted as single-person households);
2. Number of total households by size (four categories: 1, 2, 3 or 4+);
3. Number of households by income quantile (four income quantiles as defined in Table 7);
4. Number of households by number of workers (four categories: 0, 1, 2, 3+);
5. Number of persons by age (five categories: 0-4, 5-19, 20-44; 45-64; 65+) and,
6. Number of persons living in non-institutionalized group quarters by type (three categories: college dorm, military, and other non-institutional group quarters)

27 PopulationSim: https://activitysim.github.io/populationsim/.

Travel Model

Travel models are frequently updated. As such, a bit of detail as to which version of a given travel model is used for a given analysis is useful. The current analysis uses MTC's Travel Model 1.5 (version 1.5.2.3), released in December 2020, calibrated to year 2015 conditions, and validated against year 2010 and 2015 conditions.[28] Travel Model 1.5 will also be referred to as TM1.5 for the purposes of this report.

Travel Model 1.5 is of the so-called "activity-based" archetype. The model is a partial agent-based simulation in which the agents are the households and people who reside in the Bay Area. The simulation is partial because it does not include the simulation of individual behavior of passenger, commercial, and transit vehicles on roadways and transit facilities (though the model system does simulate the behavior of aggregations of vehicles and transit riders). In regional planning work, the travel model is used to simulate a typical weekday – when school is in session, the weather is pleasant, and no major collisions or incidents disrupt the transportation system.

The model system operates on a synthetic population that includes households and people representing each actual household and person in the nine-county Bay Area – in both historical and prospective years. Travelers move through a space segmented into travel analysis zones (TAZs)[29] and, in so doing, use the transportation system. The model system simulates a series of travel-related choices for each household and for each person within each household. These choices[30] are as follows (organized sequentially):

1. **Usual workplace and school location** — Each worker, student, and working student in the synthetic population selects a travel analysis zone in which to work or attend school (or, for working students, one zone to work and another in which to attend school).

2. **Household automobile ownership** — Each household, given its location and socio-demographics, as well as each member's work and/or school locations (i.e., given the preceding simulation results), decides how many vehicles to own.

3. **Daily activity pattern** — Each household chooses the daily activity pattern of each household member, the choices being (a) go to work or school, (b) leave the house, but not for work or school, or (c) stay at home.

4. Work/school tour[31] frequency and scheduling — Each worker, student, and working student decides how many round trips they will make to work and/or school and then schedules a time to leave for, as well as return home from, work and/or school.

5. **Joint non-mandatory[32] tour frequency, party size, participation, destination, and scheduling** — Each household selects the number and type (e.g., to eat, to visit friends) of "joint" (defined as two or more members of the same household traveling together for the duration of the tour) non-mandatory (for purposes other than work or school) round trips in which to engage, then determines which members of the household will participate, where, and at what time the tour (i.e., the time leaving and the time returning home) will occur.

6. **Non-mandatory tour frequency, destination, and scheduling** — Each person determines the number and type of non-mandatory (e.g., to eat, to shop) round trips to engage in during the model day, where to engage in these tours, and at what time to leave and return home.

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28 Additional information is available here: https://github.com/BayAreaMetro/modeling-website/wiki/Development.

29 Map of TAZs: https://mtc.maps.arcgis.com/home/item.html?id=b85ba4d43f9843128d3542260d9a2f1f

30 These "choices", which often are not really choices at all (the term is part of travel model jargon), are simulated in a random utility framework – background information is available here: https://en.wikipedia.org/wiki/Choice_modelling.

31 A "tour" is defined as a round trip from and back to either home or the workplace.

32 Travel modeling practice use the term "mandatory" to describe work and school travel and "non-mandatory" to refer to other types of travel (e.g., to the grocery store); this terminology is used to communicate efficiently with others in this space. Staff neither assume nor believe that all non-work/school-related travel is non-mandatory or optional.

7. Tour travel mode — The tour-level travel mode choice (e.g., drive alone, walk, take transit) decision is simulated separately for each tour and represents the best mode of travel for the round trip.
8. Stop frequency and location — Each traveler or group of travelers (for joint travel) decides whether to make a stop on an outbound (from home) or inbound (to home) leg of a travel tour, and if a stop is to be made, where the stop is made, all given the round trip tour mode choice decision.
9. Trip travel model — A trip is a portion of a tour, either from the tour origin to the tour destination, the tour origin to a stop, a stop to another stop, or a stop to a tour destination. A separate mode choice decision is simulated for each trip; this decision is made with awareness of the prior tour mode choice decision.
10. Assignment — Vehicle trips for each synthetic traveler are aggregated into time-of-day-specific matrices (i.e., tables of trips segmented by origin and destination) that are assigned via the standard static user equilibrium procedures to the highway network. Transit trips are assigned to time-of-day-specific transit networks.

Travel Model 1.5 is a major update to Travel Model One v0.6, which was used for the previous long-range plan (Plan Bay Area 2040). Developed to support the needs of Plan Bay Area 2050, Travel Model 1.5 added representation for ride-hailing (or Transportation Network Company - TNC) and taxi modes, as well as for autonomous vehicles.[33]

The Travel Model 1.5 system inherits without significant modification the representation of interregional and commercial vehicle travel from MTC's previous travel model system (commonly referred to as BAYCAST or BAYCAST-90). Specifically, commercial vehicle demand is represented using methods developed for Caltrans and Alameda County as part of the Interstate 880 Intermodal Corridor Study conducted in 1982 and the Quick Response Freight Manual developed by the United States Department of Transportation in 1996. When combined, these methods estimate four classes of commercial travel, specifically: "very small" trucks, which are two-axle/four-tire vehicles; "small" trucks, which are two-axle/six-tire vehicles; "medium" trucks, which are three-axle vehicles; and, "combination" trucks, which are truck/trailer combinations with four or more axles.

Reconciling travel demand with available transportation supply is particularly difficult near the boundaries of planning regions because little is assumed to be known (in deference to efficiency – the model must have boundaries) about the land development patterns — the primary driver of demand — or supply details beyond these boundaries. The typical approach to representing this interregional travel is to first estimate the demand at each location where a major transportation facility intersects the boundary and to then distribute this demand to locations either within the planning region (which results in so-called "internal/external" travel) or to other boundary locations ("external/external" travel). MTC uses this typical approach and informs the process with the Census Transportation Planning Product (CTPP) based on 2006-2010 5-year American Community Survey Data, which are allocated via simple method to represent flows to and from MTC's travel analysis zones and 21 boundary locations, as well as the flows between boundary locations.

The travel of air passengers to and from the Bay Area's airports is represented with static (across alternatives), year-specific vehicle trip tables. These trip tables are based on air passenger survey data collected in 2006 and planning information developed as part of MTC's Regional Airport Planning Study.

Similarly, the travel of high-speed rail (HSR) passengers to and from the Bay Area's expected HSR stations is represented with static (across those alternatives for which HSR is assumed to be implemented), year-specific vehicle trip tables. The HSR demand estimates are derived from the California High Speed Rail Authority's 2016 Business Plan[34] with modifications to delay service based on the 2020 Business Plan.[35] The update assumes that the Gilroy and San Jose stations open around 2035, and the Millbrae and San Francisco stations open by 2040 [opening years rounded to nearest five-year increment; opening contingent on high-speed rail investments in Period 2 of Plan Bay Area 2050].

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33 For more detail about Travel Model 1.5, see: https://github.com/BayAreaMetro/modeling-website/wiki/TravelModel1.5.

34 https://hsr.ca.gov/docs/about/business_plans/2016_BusinessPlan.pdf.

35 https://hsr.ca.gov/docs/about/business_plans/2020_Business_Plan.pdf.

Vehicle Emissions Model

The MTC travel model generates spatially- and temporally-specific estimates of vehicle usage and speed for a typical weekday. This information is then input into an emissions model to estimate on-road mobile source criteria pollutants as well as carbon dioxide emissions (used as a proxy for all greenhouse gases). For the current plan air quality analyses, MTC and ABAG used the California Air Resource Board's EMissions FACtor (EMFAC) 2014 for SB 375 calculations, EMFAC 2017 for Plan Bay Area 2050 Equity Analysis calculations, CT-EMFAC 2017 for Plan Bay Area 2015 EIR mobile source air toxic emission inventory estimation, and EMFAC 2021 for Plan Bay Area 2050 EIR criteria pollutant emission inventory estimation.

Input Assumptions

Analysis work was done to simulate historical conditions, conditions in future years should no action be taken, and conditions in future years under a variety of planned modifications representing the Plan and EIR Alternatives. Historical scenarios are labeled by their year and include Year 2005 and Year 2015. Planned actions include varying sets of strategy packages. As described in EIR Alternatives section of Chapter 3: Land Use Model, there are three planned sets of strategy actions: the Plan as well as EIR Alternative 1 and EIR Alternative 2. These simulations were performed for 2025, 2030, 2035, 2040 and 2050. The no action alternative is referred to as No Project; No Project simulations were performed for the same years as the Plan and EIR Alternatives 1 and 2, but this report will focus on Year 2050 for the No Project, the Plan and the EIR Alternatives. The various simulation years serve different purposes: historical years demonstrate the model's ability to adequately replicate on-the-ground conditions[36] and provide the reader data for a familiar scenario; the California Air Resources Board established greenhouse gas targets for 2035; the regional plan, as guided by federal regulations, extends to 2050. Interim year (2025, 2030 and 2040) modeling is performed primarily for air quality conformity analysis.

The above strategy packages differ across four dimensions, namely land use, roadway supply, transit supply, and prices. Land use refers to the locations of households and jobs (of different types). Roadway supply is the physical network upon which automobiles, trucks, transit vehicles, bicycles, and pedestrians travel. Transit supply refers to the facilities upon which public transit vehicles travel (the roadway, along rail lines, ferry routes, and other dedicated infrastructure), as well as the stop locations, routes, and frequency of transit service. Prices include the monetary fees users are charged to board transit vehicles, cross bridges, operate and park private vehicles, and use express lanes (also known as high occupancy toll lanes).

36 Details of this "validation" process are available here: https://github.com/BayAreaMetro/modeling-website/wiki/Development.

Table 27. Travel model simulations by year and alternative

	SIMULATION YEAR						
Scenario	2005	2015	2025	2030	2035	2040	2050
Historical	✓	✓					
No Project			✓	✓	✓	✓	✓
Plan			✓	✓	✓	✓	✓
Incremental Progress Assessment					✓		
EIR Alternative 1					✓		✓
EIR Alternative 2					✓		✓

In the remainder of this chapter, each of the six scenarios (the rows in Table 27) are discussed, organized by the above four dimensions; additional notes on "other assumptions" concludes the section. This organization should allow the reader to compare the input assumptions across scenarios.

Land Use

Additional information regarding the land development patterns is available in Chapter 3: Land Use Model. Here, we provide a handful of details regarding the transformation of these land use inputs into the information needed by the travel model.

Prior to executing the travel model, the land development inputs provided by the Regional Growth Forecast (Table 8) and by Bay Area UrbanSim 2 (distribution details) are run through the population synthesizer as described above. The journey from control totals through the modeling system introduces minor inconsistencies between the estimated regional control totals, which are carried through Bay Area UrbanSim 2, and the totals implied by the synthetic population. These inconsistencies are presented in Table 28 confirm this matches final EIR runs.

Table 28. Demographic statistics of control and simulated populations

		HOUSEHOLDS				POPULATION		
Year	Alternative	Regional Forecast Households	Group Quarters	Synthetic Population	Percent Difference†	Regional Forecast Results	Synthetic Population	Percent Difference
2015	Historical	2,677,000	91,000	2,792,000	0.9%	7,656,000	7,581,000	-1.0%
2025	Plan	2,952,000	149,000	3,056,000	-1.4%	8,231,000	8,235,000	0.0%
2030	Plan	3,209,000	158,000	3,321,000	-1.4%	8,553,000	8,602,000	0.6%
2035	Incremental Progress	3,495,000	165,000	3,658,000	0.0%	9,003,000	9,009,000	0.1%
2035	No Project	3,495,000	167,000	3,613,000	-1.3%	9,003,000	9,168,000	1.8%
2035	Plan	3,495,000	167,000	3,613,000	-1.3%	9,003,000	9,167,000	1.8%
2035	EIR Alt1	3,495,000	167,000	3,613,000	-1.3%	9,003,000	9,168,000	1.8%
2035	EIR Alt2	3,495,000	167,000	3,613,000	-1.3%	9,003,000	9,170,000	1.9%
2040	Plan	3,711,000	176,000	3,836,000	-1.3%	9,487,000	9,546,000	0.6%
2050	No Project	4,043,000	176,000	4,183,000	-0.9%	10,325,000	10,367,000	0.4%
2050	Plan	4,043,000	176,000	4,183,000	-0.9%	10,325,000	10,368,000	0.4%
2050	EIR Alt1	4,043,000	176,000	4,183,000	-0.9%	10,325,000	10,367,000	0.4%
2050	EIR Alt2	4,043,000	176,000	4,183,000	-0.9%	10,325,000	10,363,000	0.4%

† – Individuals living in group quarters are considered individual households in the synthetic population and, subsequently, the travel model.

A key function of the population synthesizer is to identify each member of the representative populous with one of eight “person type” labels. Each person in the synthetic population is identified as a full- time worker, part-time worker, college student, non-working adult, retired person, driving-age student, non-driving-age student, or child too young for school. The travel model relies on these person type classifications, along with myriad other variables, to predict behavior.

Figure 21. Historical and forecasted person type distributions for Plan

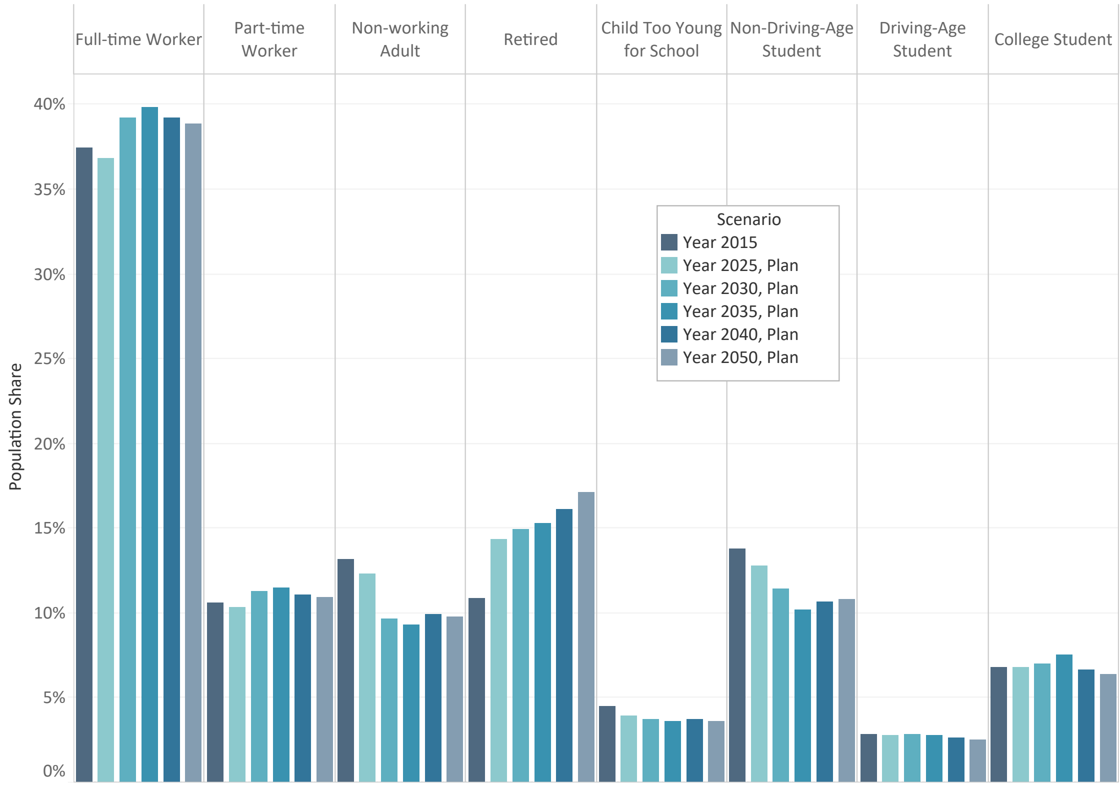
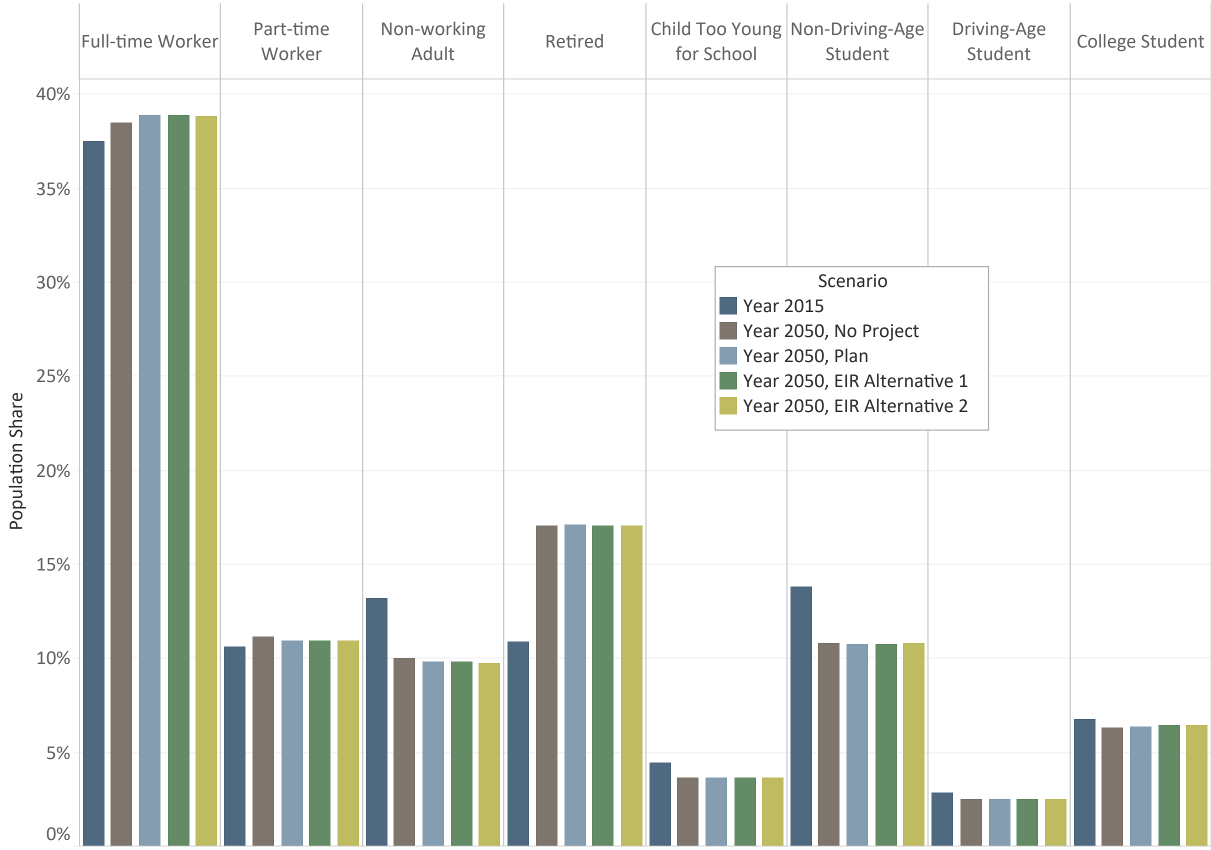


Figure 21 shows the distribution of person types for the historical scenarios and the Plan, from years 2015 to 2050. Interesting aspects of these distributions, which are driven by assumptions embedded in the regional forecast, are as follows:

1. The share of full-time workers peaks in 2035;
2. The share of retired workers steadily increases from 2015 to 2050; and
3. The person types don't change dramatically.

Figure 22 shows the distribution of person types across the four forecast year alternatives for year 2050.

Figure 22. Person type distributions across alternatives



Road Network

The historical scenarios for 2005 and 2015 have a representation of roadways that reflect infrastructure that was in place in 2005 and 2015.

The No Project alternative includes projects that are either in place in 2016 or are "committed" as defined by MTC Resolution No. 4182. The Plan (and EIR Alternatives 1 and 2) builds upon these networks, adding in the roadway projects included in the transportation investment strategies, which is discussed in more detail in Strategy Implementation. Finally, because the No Project alternative does not include EN1: Adapt to Sea Level Rise, the networks built for No Project lose some lane miles due to flooding.

A graphical depiction of the changes in the roadway network is presented Figure 23. The chart shows the change in lane-miles (e.g., a one-mile segment of a four-lane road is four lane-miles) available to automobiles in year 2050 relative to year 2015. San Francisco County shows a decrease in lane-miles, primarily due to the Market Street closure that started in 2020 as well as some conversions of roadway segments to dedicated bus ways. Figure 24 shows the change in lane-miles over time for the Plan.

Figure 23. Growth in roadway lane miles (relative to 2015) available to automobiles across alternatives

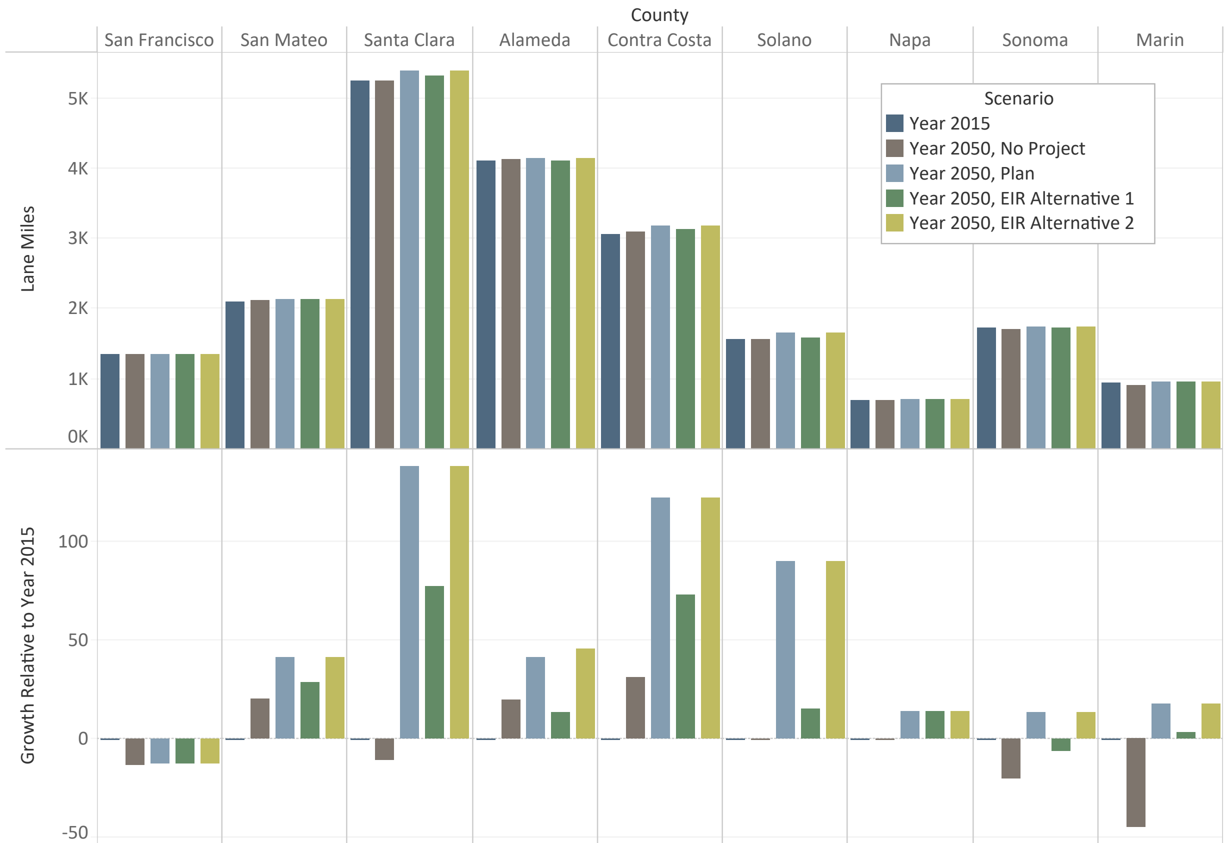
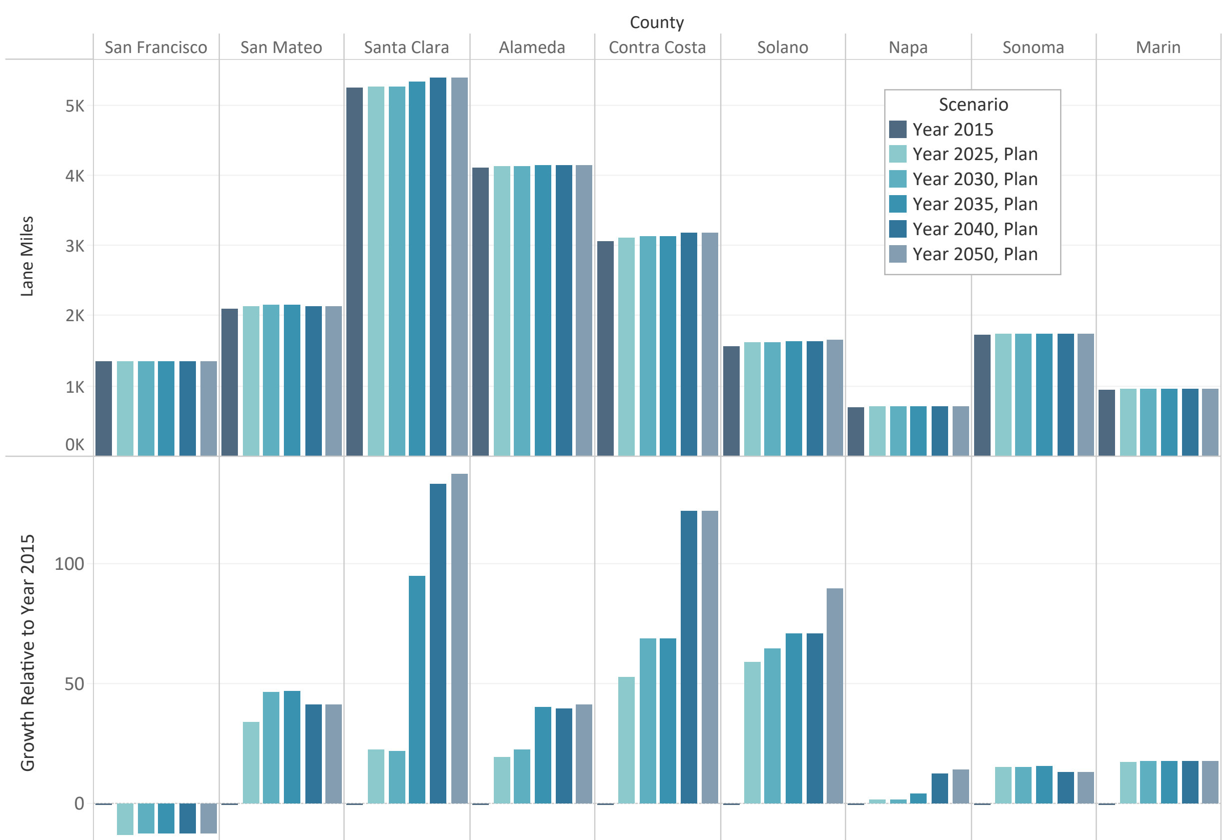


Figure 24. Growth in roadway lane miles (relative to 2015) available to automobiles in the Plan



Transit Network

The historical scenarios for 2005 and 2015 reflect service in these years.

The No Project alternative begins with 2015 service levels and adds projects that are committed as defined by MTC Resolution No. 4182. The Plan alternative begins with 2015 service levels and adds both the committed projects as well as those included in the transportation investment strategies, described in more detail in the Strategy Implementation section below.

The onset of the COVID-19 pandemic in early 2020 significantly altered on-the-ground service provision and created uncertainty around the levels of transit service provision in near-term future model years (2025, 2030 and 2035). While current and future funding availability and service levels continue to evolve, modeling work for Plan Bay Area 2050 used a conservative approach to represent transit service provision in the No Project Alternative. It was assumed that transit headways would increase in 2025, 2030 and 2035 commensurate to the expected percentage decrease in future funding available for transit operations. Headways were increased across all operators by 8% in the No Project for years 2025, 2030 and 2035. As planned projects increase the total service hours in the Plan and EIR Alternatives, a smaller percentage increase was applied to all transit service so that the total service hours cut were equivalent between the No Project, Plan and EIR Alternatives in 2025 and 2030. This translated to a 6.7% increase in service hours (once planned service increases from projects were applied) in the 2025 Plan and a 6.4% increase in the 2030 Plan. The plan includes an investment to return transit service levels to 2019 levels no later than 2035, so no percentage increase in headways was modeled in the Plan and EIR Alternatives for 2035. Headways in the No Project were assumed to return to the pre-pandemic baseline starting in 2040.

A graphical depiction of the changes in transit service is presented in Figure 25 below. The chart shows the change in seat-miles (e.g., a one-mile segment of a bus with 40 seats is 40 seat-miles) by mode in year 2050 compared to year 2015 across alternatives. Figure 26 shows the change in seat-miles over time by technology for the Plan.

Figure 25. Change in transit passenger seat miles (relative to year 2015) by technology across alternatives

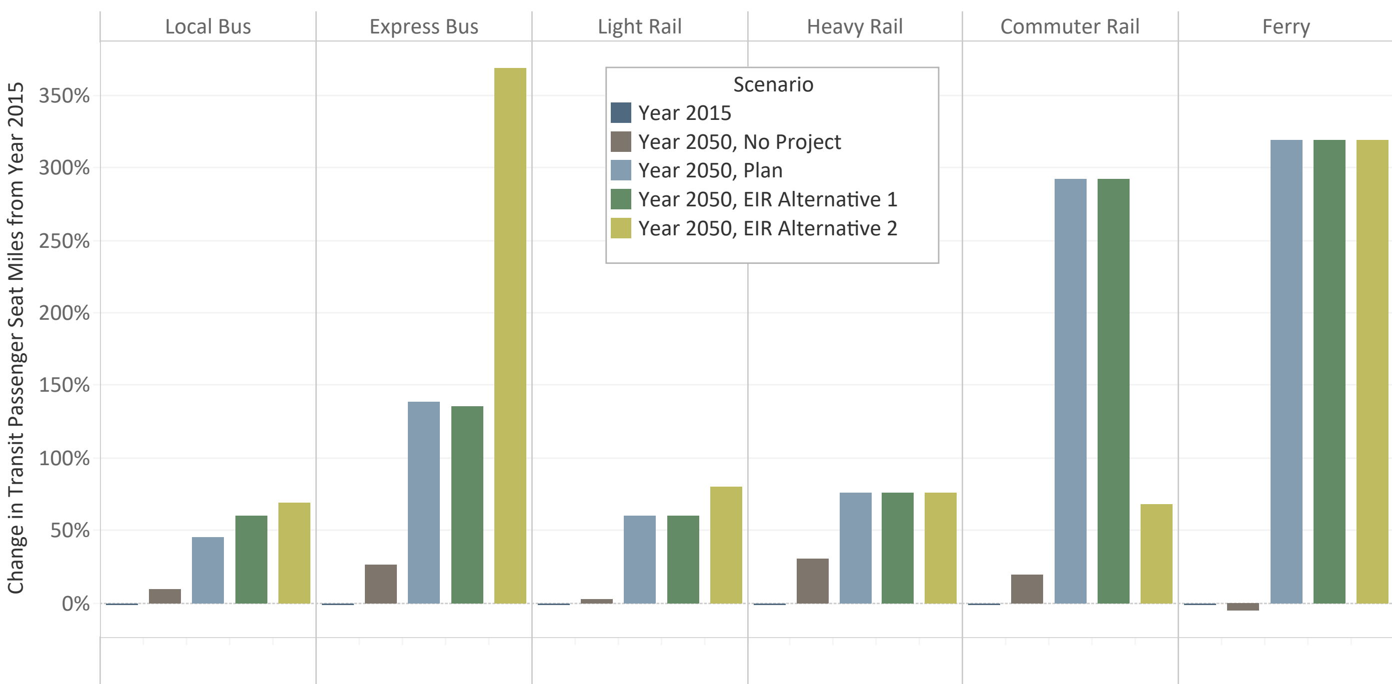
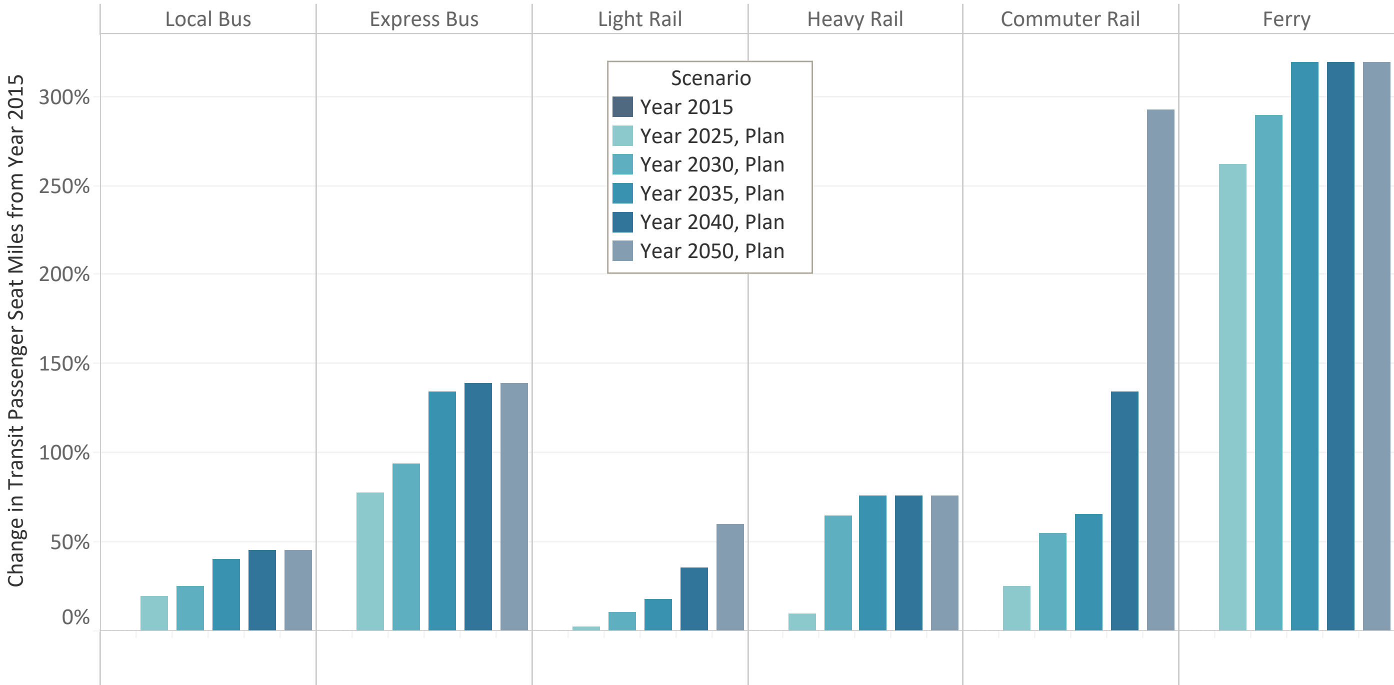


Figure 26. Change in transit passenger seat miles over time (relative to 2015) by technology in the Plan



Prices

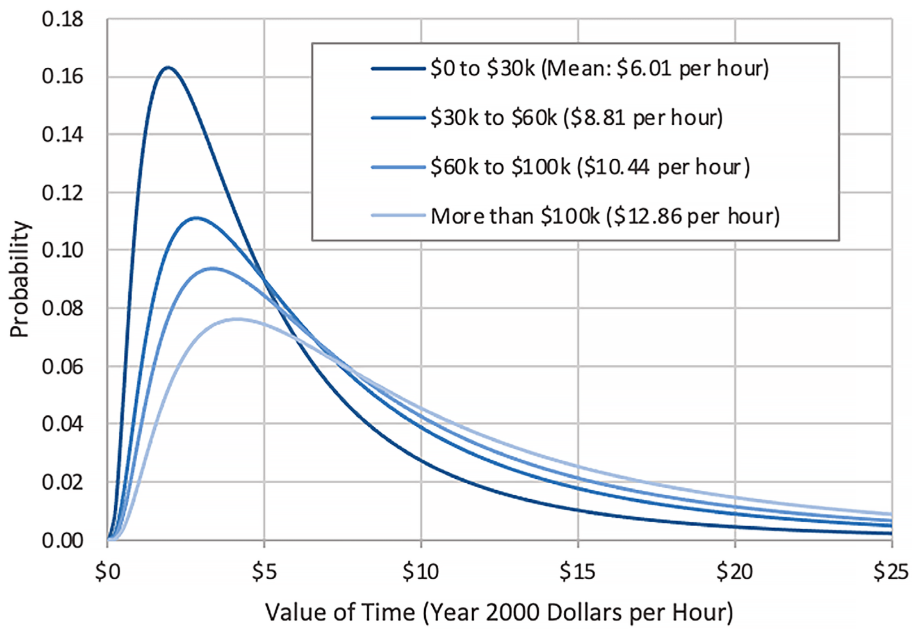
The travel model system includes probabilistic models in which travelers select the best travel mode (e.g., automobile, transit, bicycle, etc.) for each of their daily tours (round trips) and trips. One consideration of this choice is the trade-off between saving time and saving money. For example, a traveler may have two realistic options for traveling to work: (i) driving, which would take 40 minutes (round trip) and cost $10 for parking; or (ii) taking transit, which would take 90 minutes (round trip) and cost $4 in bus fare ($2 each way). The mode choice model structure, as estimated in the early 2000s, includes coefficients that dictate how different travelers in different contexts make decisions regarding saving time versus saving money. These model coefficients value time in units consistent with year 2000 dollars, i.e., the model itself – not an exogenous input to the model – values time relative to costs in year 2000 dollars. Because re-estimating model coefficients is “expensive” (in terms of staff time and/or consultant resources), it is done infrequently, which in effect “locks in” the dollar year in which prices are input to the travel model. To use the model’s coefficients properly, all prices must be input in year 2000 dollars. In the remainder of this document, prices are presented both in (close to) 2020 dollars, to give the reader an intuitive sense of the magnitude of the input prices, as well as year 2000 dollars, which are the units required by the model coefficients.

Six different types of prices are explicitly represented in the travel model: (i) bridge tolls; (ii) express lane or per-mile roadway tolls; (iii) transit fares; (iv) parking fees; (v) perceived automobile operating cost; and (vi) cordon tolls. A brief discussion on how the model determines each synthetic traveler’s value of time is presented next, after which the input assumptions across each of these price categories are presented.

Value of Time

The model coefficients that link the value of time with the other components of decision utilities remain constant between the baseline and forecast years, with the one exception of the coefficients on travel cost. These coefficients are a function of each synthetic individual's value of time, a number drawn, in both the historical and forecast year simulations, from one of four log-normal distributions (see Figure 27). The means of these distributions are a function of each traveler's household income (see Table 7). The value of time for children in a household is equal to two-thirds that of an adult. The means and shapes of these distributions remain constant across forecast years and scenarios.

Figure 27. Value of time distribution by household income category



Bridge Tolls

The bridge tolls assumed in 2015 and 2050 are shown below in Table 29. The bridge tolls for future years (all alternatives) follow the scheduled increase in in Regional Measure 3.[37]

Table 29. Common peak period bridge tolls in 2015 and 2050

	TOLLS IN YEAR 2015				TOLLS IN YEAR 2050			
	In 2015 Dollars		In 2000 Dollars		In 2020 Dollars		In 2000 Dollars	
Bridge	Base Toll	Carpool Toll	Base Toll	Carpool Toll	Base Toll	Carpool Toll	Base Toll	Carpool Toll
Antioch Bridge	5.00	2.50	3.50	1.75	8.00	4.00	4.29	2.15
Bay Bridge	6.00	2.50	4.20	1.75	9.00	4.00	4.83	2.15
Benicia - Martinez Bridge	5.00	2.50	3.50	1.75	8.00	4.00	4.29	2.15
Carquinez Bridge	5.00	2.50	3.50	1.75	8.00	4.00	4.29	2.15
Dumbarton Bridge	5.00	2.50	3.50	1.75	8.00	4.00	4.29	2.15
Golden Gate Bridge	6.75	4.75	4.72	3.32	8.75	6.75	4.70	3.62
Richmond - San Rafael Bridge	5.00	2.50	3.50	1.75	8.00	4.00	4.29	2.15
San Mateo - Hayward Bridge	5.00	2.50	3.50	1.75	8.00	4.00	4.29	2.15

Express Lane and Per-Mile Roadway Tolls

MTC's travel model explicitly represents the choice of travelers to pay a toll to use an express lane (i.e., a high-occupancy toll lane) in exchange for the time savings offered by the facility relative to the parallel free ("general purpose") lanes. To represent this functionality, MTC staff assigns a toll price by time of day and vehicle class on each tolled link in the network. To simulate the impacts of the tolled lanes efficiently and transparently on behavior, the tolled lane network is segmented within each scenario into logical segments, with each segment receiving a time-of-day-specific per mile fee. To illustrate the detail involved in this coding, Figure 28 (abstractly) presents the morning commute period price for the year 2050 simulations. Please note that the simulated prices are not perfectly optimal, although staff modeled the Plan iteratively to find the prices that meet a pre-defined operational goal – an average speed of 45mph or higher in any time period. The logic used in the toll optimization script is described in Table 30 below. Importantly, the prices are held constant over four-hour morning (6 to 10 a.m.) and evening (3 to 7 p.m.) commute periods. MTC's travel model makes the simplifying assumption that congestion is uniform over the entire four-hour commute periods. The peak one-hour within the four-hour commute period would require a higher toll than those simulated in the model.

37 https://mtc.ca.gov/sites/default/files/BATA%202019%20Toll%20Schedule%20Dec%202018.pdf

Figure 28 also depicts the roadways that comprise the per-mile tolling strategy in the Plan. More details are provided in the section on Strategy T5 to Strategy T5: Implement Means-Based Per-Mile Tolling on Congested Freeways with Transit Alternatives. Additionally, the figure shows the SR-37 corridor, which would be tolled to fund sea level rise adaptation measures on the corridor in the Plan.

Figure 28. Morning commute express lane tolls (in 2000$) for the No Project and Plan alternatives in 2050

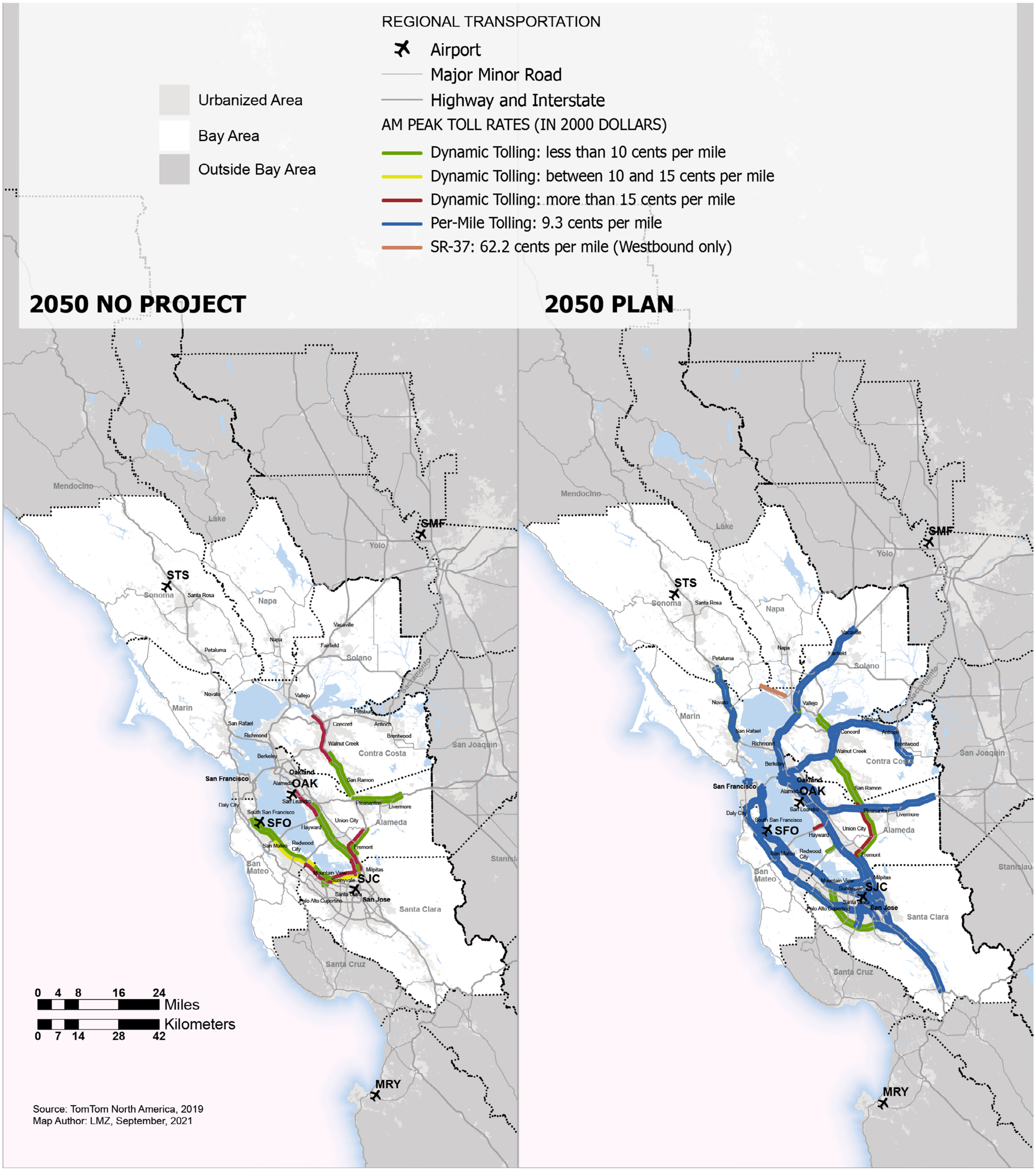


Table 30. Logic used in the toll optimization process

CASE #	EXPRESS LANE (EL) SPEED (MPH)	GENERAL PURPOSE LANE (GP) SPEED (MPH)	INTERPRETATION AND ACTION
Case 1	<=48*	any	EL too slow; increase toll rate.
Case 2	>48	<=40	GP too slow; decrease toll rate.
Case 3	48-60	40-60	OK; no change in toll rate.
Case 4	>60	40-60	GP speed can be improved; decrease toll rate.
Case 5	>48	>60	Set toll to minimum, i.e. 3 cents (2000$) per mile in morning peak, midday, and afternoon peak for drive alone

*Note: The threshold used in the toll optimization script is 48mph, which is slightly higher than the performance target of 45mph. This is because average speeds in toll optimization runs (which only execute only CTRAMP and highway assignment) can be slightly different from the full model run (which includes transit assignment). Setting the threshold slightly higher than the actual performance target makes sure the average speeds in the full model run do not go below 45mph.

Transit Fares

The forecast year transit networks pivot off a year 2015 baseline network (i.e., the alternatives begin with 2015 conditions and add/remove service to represent the various alternatives in future years). The transit fares in 2015 are assumed to remain constant (in real terms) in all forecast years. Staff are therefore explicitly assuming transit fares will keep pace with inflation and that transit fares will be as expensive in the forecast year as they are today, relative to parking prices, bridge tolls, etc. As a simplification, we assume travelers pay the cash fare to ride each transit service. Table 31 includes year 2015 fare prices expressed in both year 2000 and year 2015 dollars.

Table 31. Fare prices (in 2015$ and 2000$) by operator in 2015

OPERATOR	FARE IN 2015 DOLLARS	FARE IN 2000 DOLLARS
West Berkeley Shuttle	Free	Free
Broadway Shuttle	Free	Free
Emery Go-Round	Free	Free
Stanford Shuttles	Free	Free
Caltrain Shuttles	Free	Free
VTA Shuttles	Free	Free
Palo Alto/Menlo Park Shuttles	Free	Free
WHEELS Ace Shuttles	Free	Free
Amtrak Shuttles	Free	Free
Burlingame Shuttle	Free	Free
MUNI - Cable Cars	7.00	4.74
MUNI - Local	2.25	1.52
SamTrans Local	2.00	1.35
VTA - Community Bus	1.25	0.85
VTA - Regular & Limited	2.00	1.35
AC Transit Local	2.00	1.35
WHEELS - Local	2.10	1.42
Union City Transit	2.00	1.35
County Connection (CCCTA) - Local	2.00	1.35
Tri Delta Transit	2.00	1.35
WESTCAT Local	1.75	1.19
SolTrans - Local	1.75	1.19
Fairfield And Suisun Transit - Local	1.75	1.19

OPERATOR	FARE IN 2015 DOLLARS	FARE IN 2000 DOLLARS
American Canyon Transit	1.00	0.68
Vacaville City Coach	1.60	1.08
VINE (Napa County) - Local	1.60	1.08
Sonoma County Transit - Local	1.50	1.02
Santa Rosa CityBus	1.50	1.02
Petaluma Transit	1.50	1.02
Golden Gate Transit - Local	1.80	1.22
SamTrans - Express	2.00	1.35
VTA - Express	4.00	2.71
Dumbarton Express	2.10	1.42
AC Transit - Transbay	4.20	2.84
County Connection (CCCTA) - Express	2.25	1.52
Golden Gate Transit - Express	5.00	3.39
Golden Gate Transit - Richmond	4.40	2.98
WESTCAT - Express	5.00	3.39
SolTrans - Express	1.75	1.19
Fairfield and Suisun Transit - Express	2.75	1.86
VINE (Napa County) - Express	3.25	2.20
MUNI Metro	2.25	1.52
VTA - Light Rail	2.00	1.35

For SamTrans Express and SolTrans Express, the local fare is initially applied. An additional fare is paid as the Express lines traverse screen lines outside the service area for local bus service. For rail and ferry service, the fares vary based on posted fares between individual stations/terminals.

Parking Prices

The travel model segments space into travel analysis zones (TAZs). Simulated travelers move between TAZs and, in so doing, burden the transportation network. Parking costs are applied at the TAZ level: travelers going to zone X in an automobile must pay the parking cost assumed for zone X.

The travel model uses hourly parking rates for daily/long-term (those going to work or school) and hourly/short-term parkers. The long-term hourly rate for daily parkers represents the advertised monthly parking rate, averaged for all lots in a given TAZ, scaled by 22 days per month, then scaled by 8 hours per day; the short-term hourly rate is the advertised hourly rate — generally higher than the rate daily parkers pay — averaged for all lots in a given TAZ. Priced parking in the Bay Area generally occurs in greater downtown San Francisco, downtown Oakland, Berkeley, downtown San Jose, and Palo Alto.

When forecasting, it is assumed that parking prices change over time per a simple model: parking cost increases in line with employment density. Across the scenarios, therefore, the parking charges vary with employment density according to their land use input. For the Plan and EIR Alternatives 1 and 2, additional parking pricing is included, as described in more detail in the following Strategy Implementation section.

Perceived Automobile Operating Cost

When deciding between traveling in a private automobile or on a transit vehicle (or by walking, bicycling, etc.), the modeling process assumes travelers consider the cost of operating and maintaining, but not owning and insuring, their automobiles. The following three inputs are used to determine the perceived automobile operating cost: average fuel price, average fleet-wide fuel economy, and non-fuel related operating and maintenance costs.

To improve consistency among regional planning efforts across the state, the Regional Targets Advisory Committee (formed per Senate Bill 375) recommended that California's metropolitan planning organizations (MPOs) use consistent assumptions for fuel price and for the computation of automobile operating cost in long range planning. The assumptions for Plan Bay Area 2050 build off the multi-agency methodology developed by the four largest MPOs for the previous round of regional plans, as well as resources provided by the California Air Resources Board (CARB). The fuel price forecasts use projections generated by the United States Department of Energy (DOE) and California Energy Commission (CEC). Gas tax rates are added to base fuel price forecasts to project total fuel cost rates. The average fleet-wide fuel economy implied by CARB's EMFAC2017 model is used to represent the average fleet-wide fuel economy. Non-fuel operating and maintenance costs are based on data from AAA and forecasted using growth assumptions developed in the multi-MPO methodology. A summary of assumptions is presented in Table 32. Note that the prices in the table are presented in year 2017 dollars, year 2010 dollars (the units used in the above referenced documentation), and year 2000 dollars (the units of the travel model).

Table 32. Perceived automobile operating cost assumptions

MEASURE	ANALYSIS YEAR	
	2015	2050
Average fuel price (Year 2000 dollars per gallon)	$2.19	$3.22
Average fuel price (Year 2010 dollars per gallon)	$2.77	$4.06
Average fuel price (Year 2017 dollars per gallon)	$3.35	$4.91
EMFAC-implied fuel economy (miles per gallon)	23.48	44.23
Non-fuel-related operating cost ($2000 per mile)	$0.04	$0.10
Non-fuel-related operating cost ($2010 per mile)	$0.06	$0.13
Non-fuel-related operating cost ($2017 per mile)	$0.07	$0.16
Perceived automobile operating cost ($2000 per mile) †	$0.14	$0.17
Perceived automobile operating cost ($2010 per mile) †	$0.17	$0.22
Perceived automobile operating cost ($2017 per mile) †	$0.21	$0.27

† – Sum of the fuel-related operating cost (fuel price divided by fuel economy) and non-fuel-related operating cost.

New Model Features and Associated Assumptions

Ride-Hailing

Since Plan Bay Area 2040, a key enhancement made to the Travel Model is the explicit representation of ride-hailing modes, including Taxi and Transportation Networking Companies (TNCs) such as Uber and Lyft. Specifically, the tour and trip-based mode choice models have been modified to include a new ride-hailing nest.[38] This new nest has three sub-alternatives: traditional taxi, non-pooled TNC (e.g. UberX) and pooled TNC (e.g. UberPool).

Tour and Trip Mode Choice Utilities

For all three ride-hailing modes, the tour and trip mode choice utilities are specified as a function of in-vehicle time, wait time, cost (including fares, bridge tolls, road tolls), an alternative-specific constant, and a “TNC availability adjustment” constant. Table 33 below summarizes the assumptions used in these utility components in the Plan and EIR Alternatives.

38 The mode choice model is a nested logit model. Choices within the same “nest” in a model are closer substitutes to one another than other choices.

Table 33. Taxi and TNC utility components in Plan Bay Area 2050 modeling

UTILITY COMPONENTS	VARIABLE	COEFFICIENTS
In-vehicle time	For taxi and non-pooled TNC: travel time is generated from the network modeling component of the Travel Model. For pooled TNC: a multiplier of 1.5 is applied to the travel time of non-pooled TNC, to reflect detours taken to pick-up or drop-off additional customers.[39]	Generic in-vehicle coefficient (i.e., same coefficient used in drive alone and other modes)
Wait time	Simulated from distribution Taxi and TNC mode wait times are simulated from distributions that were estimated based on a survey of actual taxi and TNC wait times conducted in the Portland region in 2015.[40] Lognormal distributions were estimated from this observed data for each mode according to the land-use density of the tour or trip origin.	1.5 times the in-vehicle time coefficient (to represent that time spent on waiting is more onerous than time spent in vehicle)
Fares	A function of minimum cost, initial cost, cost per mile, distance, cost per minute, in-vehicle time Based on 2015 data.[41]	Generic cost coefficient (i.e., same coefficient used in drive alone and other modes)
Bridge tolls	Based on Regional Measure 3[42] Additionally, based on current TNC policies, it is assumed that TNC users are being charged bridge toll both ways.[43] For example, even though Golden Gate Bridge (Northbound) is free, TNC users who cross the bridge still must pay for the toll for the driver's return trip.	Generic cost coefficient (i.e., same coefficient used in drive alone and other modes)
Roadway tolls	Based on Plan tolling strategy inputs described in the section,	Generic cost coefficient (i.e., same coefficient used in drive alone and other modes)
Alternative-specific constant	Different constant for the three ride-hailing modes and for different household car-sufficiency level (0 car, fewer cars than workers, or more cars than workers)	Calibrated based on 2015 data. See detail in Travel Model 1.5 Calibration and Validation documentation[44]
TNC availability adjustment	A user-defined parameter to account for presumed wider availability compared to base year. Expressed in terms of minutes of "in-vehicle travel time equivalent"	Base year = calibrated Future-year (2050) = asserted to be 15 minutes of in-vehicle travel time equivalent (deducted from the utility, making TNCs more attractive)

39 For shared TNCs, an in-vehicle time multiplier of 1.5 is applied to reflect detours taken to pick-up or drop-off additional customers. The factor of 1.5 was used in the Plan run, based on data collected in Chicago between November 2017 to March 2018 (Schwieterman and Livingston (2018) available on https://las.depaul.edu/centers-and-institutes/chaddick-institute-for-metropolitan-development/research-and-publications/Documents/Uber%20Economics_Live.pdf).

40 See: https://www.portlandmercury.com/images/blogimages/2015/07/10/1436550157-uber_taxi_report.pdf). The only modification to the empirical distribution was that for the highest density area type we reduced the mean wait time slightly, from 4.7 minutes to 3 minutes, to represent presumed shorter wait time in the highest density areas in San Francisco compared to Portland.

41 See details in: https://github.com/BayAreaMetro/modelingwebsite/wiki/TravelModel1.5#Ridehailing_and_Taxi_Modes.

42 See: https://mtc.ca.gov/sites/default/files/BATA%202019%20Toll%20Schedule%20Dec%202018.pdf.

43 See the "Return Charges" section in https://help.lyft.com/hc/en-us/articles/115012927227.

44 See: https://github.com/BayAreaMetro/modeling-website/wiki/Development.

Vehicle Occupancy Assumptions and Autonomous TNCs

After mode choice and other demand model components are run, ride-hailing trips are assigned in the network modeling component of TM1.5. The total trips in each ride-hailing mode are multiplied by their vehicle occupancy factors, which determine the number of ride-hailing trips to be assigned as single-occupant, double-occupant, or 3+ occupant trips.

The vehicle occupancy factors were developed using data collected from the pilot phase of the Bay Area Transportation Study,[45] since the full survey was not available at the time of this model development work. The pilot was conducted in Fall 2018, with close to 1,300 ride-hailing trips collected.

The vehicle occupancy factors applied in the Plan are described in Table 34 below. According to data collected from the pilot of the Bay Area Transportation Study, 53% of the non-pooled TNC trips were 2-person occupancy and 47% were 3+ person occupancy in 2018 (there were no single occupancy taxi or TNC trip because each trip should have at least one driver and one passenger, except for out-of-service movement which is considered separately and will be explained in the "deadheading" section below). For future years (2035 onwards), it is assumed that TNC vehicles will become autonomous, and therefore the 53% that were 2-person occupancy are assumed to be single occupancy, and the 47% of that were 3+ person occupancy are assumed to be 2+ person occupancy. Similarly, for pooled TNC trips, the data suggests that 18% of the pooled TNC trips were 2-person occupancy (one driver plus one passenger, as the TNC did not successfully match an additional passenger for that trip) and 82% were 3+ person occupancy (one driver plus at least 2 passengers) in 2018. For future years (2035 onwards), since it is assumed that TNC vehicles will become autonomous, some percentage of the pooled TNC trips will become single occupancy. Staff assumed 9% (lower than the 18% that were 2-person occupancy in the base year) to reflect improvement in ride-matching.

45 See: https://mtc.ca.gov/our-work/plans-projects/other-plans/bay-area-transportation-study.

Table 34. TNC vehicle occupancy assumptions

		SHARE OF TRIPS BY OCCUPANCY	
Mode	Occupancy	2015	2035 and 2050
Taxi	single	0%	0%
	double	53%	53%
	three or more	47%	47%
TNC non-pooled	single	0%	53%
	double	53%	29%
	three or more	47%	18%
TNC pooled	single	0%	9%
	double	18%	29%
	three or more	82%	62%

Deadheading

Deadheading, or out-of-service movement, is the movement of a vehicle without a passenger. TNCs and taxis cruise around to look for fares and reposition before or after a paid trip. Modeling deadheading is a new area in the field of travel modeling. During the Plan Bay Area 2050 model upgrade effort, very little data about taxi and TNC deadheading behavior was available and so staff could not justify the development of a detailed deadheading model. Therefore, a simple approach was implemented, involving the application of a multiplier (a "zero-passenger vehicle-mile factor") to the transpose of the taxi and TNC trip origin-and-destination matrices to represent deadheading trips.

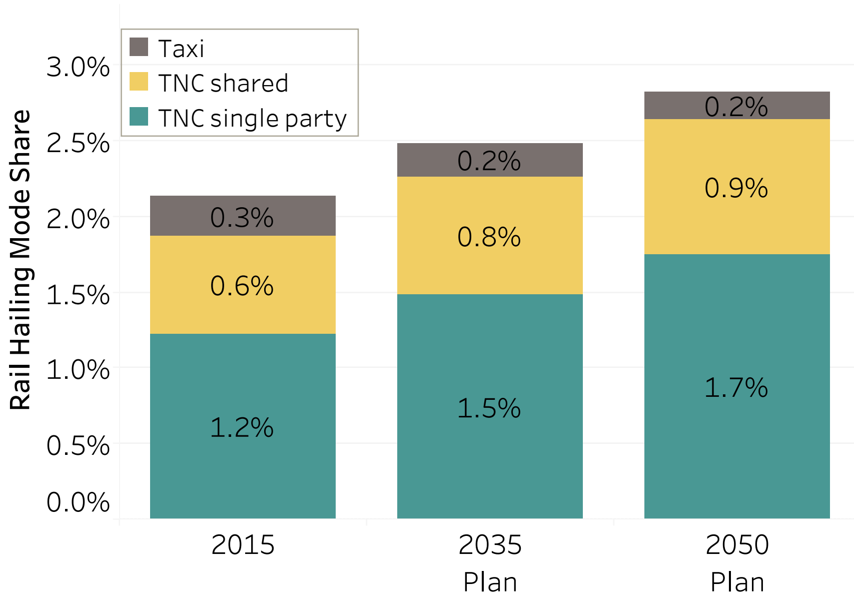
The zero-passenger vehicle-mile factor is a user-defined parameter in the model and can be easily updated when better data becomes available. Based on data from the California Public Utilities Commission (CPUC), the current assumption is that for every mile driven with passengers, a ride-hailing vehicle drives another 0.7 miles without passengers.[46] While simplistic, this method allows the model to represent the pollution and greenhouse gas emissions from the additional VMT generated from deadheading.

46 Source: aggregated statewide data released by the California Public Utilities Commission: http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Divisions/Policy_and_Planning/PPD_Work/PPD_Work_Products_(2014_forward)/Electrifying%20the%20Ride%20Sourcing%20Sector.pdf.

Modeled TNC Shares in Base and Future Years

As shown in Figure 29, future TNC mode share is expected to grow but remains a small share of the overall market, growing from 1.8% in 2015 to 2.5% in 2050 regionwide. Much of the growth is driven by the assumption that TNCs will be more widely available (via a user-defined input known as "availability adjustment" described in Table 33).

Figure 29. Modeled TNC shares



At the time of Travel Model 1.5 development for Plan Bay Area 2050, there was a dearth of available data for the calibration of TNC mode shares. Therefore, staff focused model calibration on meeting conventional calibration targets (including achieving estimated transit boardings within 10% of what is observed for each operator, and 20% percent root mean square for high volume roadway links), since reliable data about transit boardings and traffic counts exist. The underlying logic is that as long as transit boardings are within 10% of observed, then the number of TNC trips would not be too far off.

Another MTC effort, the Bay Area Transportation Study, was underway at the same time as the Plan Bay Area 2050 effort. The survey fieldwork was conducted in spring 2019. The data from the Bay Area Transportation Study was not available in time for model calibration but became available at the time of this report writing. Some key numbers from the Bay Area Transportation Study are shown in Table 35, along with a couple other key references for a retrospective model validation. Staff found that the 2015 TNC mode share erred on the high side, especially in the mode share outside San Francisco. While staff acknowledges this caveat, it is not expected to have a significant impact on the modeling GHG results since TNC represents a small share of the overall mode share. More detailed validation results (e.g., trip lengths and county-to-country trip matrices) are available in the Travel Model 1.5 Calibration and Validation documentation.

Table 35. Key references for retrospective model validation

VALIDATION DATA	VALIDATION DATA DETAIL	TM1.5	REMARK
Combined mode share for TNC and Taxi	NHTS 2017 data suggest that the combined mode share for Taxi and TNC was 0.91% on a typical weekday for the Bay Area.	2015 base year has a combined mode share for TNC and Taxi = 2.1%	Note that the NHTS data is more recent. One would expect TNC usage was lower in 2015 than 2017. Combined mode share for TNC and Taxi probably too high in the base year of TM1.5 (2015).
Vehicle trips within San Francisco	"On a typical weekday, ride-hail vehicles make more than 170,000 vehicle trips within San Francisco, approximately 12 times the number of taxi trips, representing 15 percent of all intra-San Francisco vehicle trips." (from the report TNCs Today, published in 2017, with data reflecting November and December 2016 situation)[47] CPUC data suggests that the year-on-year growth for TNC trip miles was 122% statewide between 2015 and 2016. Assuming the statewide data applies to vehicle trips within San Francisco, a rough estimate of intra-SF ride-hail trips is 77,000.	Intra-SF TNC trips = 71,000 in 2015	TNC Today's data includes TNC trips made by non-residents, and data for scaling the number to residents only is unavailable. Thus, the TNC Today number should be treated as an upper bound.
Trip mode share (San Francisco and non-SF)	San Francisco = 3.0% Non-San Francisco = 0.6% Reported in Bradley et al. (2021), Spring 2019 data. San Francisco refers to all trips to, from or within San Francisco.	San Francisco = 2.3% Non-San Francisco = 1.7%	Trip mode share for TNC in TM1.5 is probably too high outside of San Francisco.

47 SFCTA. 2017. TNCs Today — A Profile of San Francisco Transportation Network Company Activity. Draft Report. San Francisco, CA: San Francisco County Transportation Authority.

Autonomous Vehicles

One main difference between Travel Model One and the enhanced Travel Model 1.5 is the ability to incorporate different levels of autonomous vehicle (AV) market penetration. The enhancements include:

- **Auto ownership:** extended to consider ownership of both autonomous (AV) and human driven (HV) vehicles
- **AV allocation:** a simulation model was added to determine, for AV-owning households, whether an AV is allocated for a tour
- **Tour and trip mode choice:** user-defined coefficients to represent AV scenario assumptions are added
- **Zero passenger vehicle module:** a multiplier, known as the zero-passenger vehicle factor, is applied to the transpose of the AV and TNC trip matrices to represent zero passenger vehicle trips
- **Traffic assignment:** AVs (together with TNCs) are assigned as a separate vehicle class from the existing vehicle classes. This allows analysts to generate summaries specific to AVs and TNCs. Also, to represent potential increases in effective roadway capacity due to closer vehicle spacing, the traffic assignment module of TM1.5 is updated such that the passenger-car equivalent[48] of AVs is configurable by facility type.

Detailed documentation about these enhancements is available on the Travel Model 1.5 documentation wiki.[49] This report will focus on the user-defined coefficients used in Plan Bay Area 2050 modeling.

Since fully autonomous vehicles are still a nascent technology that is not available to the public yet, there is considerable uncertainty around its operational characteristics and the associated traveler behavioral responses. TM1.5 allows users to define different coefficients that represent different AV modeling assumptions. The user-defined coefficients in Plan Bay Area 2050 modeling were informed by the outcomes of a literature search, a series of presentations, a workshop and a survey of Regional Modeling Working Group[50] participants that took place in late 2018 as part of the Horizon process. These coefficients and assumptions are presented in Table 36.

Given these assumptions, the incorporation of AV use and their deadheading miles in Plan Bay Area 2050 modeling shows that the emergence of AVs has an adverse impact on the Bay Area's ability to meet its VMT and GHG reduction goals. In a test run, in which AV market penetration was set to zero while holding all else the same as the 2050 Plan scenario, the VMT per capita was 9% lower than the Plan (14.9 in the test, compared to 16.3 in the Plan).

48 PCE rates are generally determined prior to the assignment step, with values of 1.0 given to passenger vehicles and values greater than 1.0 to trucks. To simulate increase in roadway capacity due to AVs, PCEs of less than 1.0 can be assigned to the vehicles that are assumed to be autonomous.

49 Travel Model 1.5 Documentation wiki: https://github.com/BayAreaMetro/modeling-website/wiki/TravelModel1.5#Autonomous_Vehicles.

50 The Regional Modeling Working Group is comprised of planners and modelers working for transportation agencies in the San Francisco Bay Area. In 2018-2020, the working group has more than 20 active members who regularly attend the group's monthly meetings.

Table 36. Autonomous vehicle modeling assumptions

VARIABLE	VARIABLE DESCRIPTION	ASSUMPTION
Fleet Penetration	Share of total passenger vehicle fleet that is autonomous	2035: 5% 2050: 20%
Auto Ownership Likelihood by Households	Coefficients representing different likelihood of AV ownership by household types	Based on recent research for FHWA[51]
Household Use Allocation	Probability boosts representing that, for AV-owning households, AVs are more likely to be used than human-driven vehicles	The probability boost is set to 1 (i.e., the assumption was that AV and human driven vehicles are equally likely to be used within an AV owning households)
In-Vehicle Time Coefficient for Mode Choice	The marginal disutility of in-vehicle travel time	Same as human driven vehicles
Parking Cost, Per-mile Auto Operating Cost and Terminal Time	Parking and per-mile auto operating costs are self-explanatory. Terminal Time refers to the time it takes to park the vehicle and walk from the parking location to the actual destination.	Same as human driven vehicles
Zero-Passenger Vehicle Factor	Factor reflecting that every AV mile driven with passengers yields additional mileage without passengers	0.7 (i.e., for every mile driven with passengers, an AV drives another 0.7 miles without passengers)[52]
Effective Roadway Capacity	Passenger-car equivalent reflecting improved vehicle spacing	1.0 (i.e., no effective roadway capacity increased is expected given the low AV market penetration assumed in the Plan)

Telecommuting

The implementation of telecommuting was updated slightly for Travel Model 1.5 to better represent Strategy EN7: Expand Commute Trip Reduction Programs at Major Employers, described in more detail below. In the previous version of the model, telecommuting was represented by dampening the likelihood of making a mandatory tour within the Coordinated Daily Activity Pattern sub-model for workers. The Coordinated Daily Activity Pattern sub-model was estimated and calibrated for Travel Model One v0.3, which was released in April 2012. As described in that version's Calibration and Validation Technical Report,[53] the model specification was transferred from the Atlanta Regional Commission (ARC) model, and the Travel Model One calibration was based on targets from the Bay Area Travel Survey (BATS) 2000, with adjustments to offset respondents' underreporting of travel. For the modeled base year of 2015, 80.8% of full-time workers made a work tour and 19.2% of full-time workers did not make a work tour in the modeled day. When looking at all workers (including part-time), this grew to 24.2% of workers who did not make a work tour on an average workday.

51 https://www.fhwa.dot.gov/planning/tmip/publications/other_reports/model_impacts_cavs/.

52 Same factor as TNC deadheading is used. SOURCE: aggregated statewide data released by the California Public Utilities Commission: http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Divisions/Policy_and_Planning/PPD_Work/PPD_Work_Products_(2014_forward)/Electrifying%20the%20Ride%20Sourcing%20Sector.pdf.

53 Travel Model Development: Calibration and Validation - Technical Report, May 17, 2012: https://mtcdrive.box.com/s/7crr7bwhromi2au42jnpp11fqe5l24xq.

In updating the telecommuting implementation in Travel Model 1.5 for this plan, staff looked further into the data and assumptions previously made around teleworking. Workers who do not make a work tour on an average weekday may do so because they have an alternate work schedule, or because they are taking a vacation, personal or sick day, or because they are telecommuting. It is therefore necessary to assume what portion of workers who are not making work tours are doing so because they are telecommuting versus not working that day. Initially, staff looked at estimates of telecommuting from the American Community Survey's Table B08301: Means of Transportation to Work, which included data for "Worked at home." The ACS 1-year Estimates for 2015 dataset estimated that 5.6% of Bay Area workers aged 16 years and over worked at home. However, the ACS data under-represents telecommuting as defined for travel modeling, stating that the "principal means of transportation to work refers to the mode of travel used to get from home to work most frequently" (emphasis added). Therefore, this estimate does not include workers who telecommute regularly but less than the majority of the work week. Thus, staff looked at the results of the Bay Area Transportation Study[54], which surveyed Bay Area residents about their travel behavior in the fall of 2018 and the spring of 2019. This survey asked whether respondents traveled to work and/or teleworked on each day of survey participation. Using weighted data representing a "typical" (here, Monday through Thursday) weekday, the survey results of full-time workers showed dramatically higher rates of not-working, 19.9%, as well as telecommuting (with no work tours), 15.6%, with only 64.4% of workers making a work tour.

Since recalibration of the Coordinated Daily Activity Pattern sub-model was out of scope, staff did not alter the overall assumption of workers not making work tours in the 2015 base year. Therefore, staff applied the proportion from the survey: that 56.1% of full-time workers who did not go to work did not work that day, and the remainder teleworked; for part-time workers, 55.3% of workers who did not go to work did not work that day. Applying this assumption resulted in a telecommute rate assumption of 8.5% of full-time workers and 16.6% of part-time workers in the 2015 base year, and 10.3% across all full- and part-time workers. Doing a similar summary of the 2005 base year model run resulting in a telecommute rate assumption of 7.8% of full-time workers and 17.0% of part-time workers, and 9.5% across all full- and part-time workers. Staff fit an exponential curve to these two base years to extrapolate No Project telecommute rates for future years.

Table 37. Baseline telecommute rate assumption, 2005-2050, as a percentage of full- and part-time workers (including those not working on a given day)

MODEL YEAR	OVERALL TELECOMMUTE RATE ASSUMPTION
2005	9.5%
2015	10.3%
2025	11.0%
2030	11.4%
2035	11.8%
2040	12.3%
2050	13.2%

For future years, this base level of telecommute increase was represented by increasing the magnitude of a constant which would reduce the likelihood of a full-time worker making a work tour in the Coordinated Daily Activity Pattern sub-model. Because telecommuting eligibility is correlated with higher-wage occupations and occupation/industry is not attached to any individual worker in the model, this constant was applied only to workers with a household income of $50,000 or higher (in 2000 dollars). The methodology used for representing telecommuting remained unchanged from Plan Bay Area 2040; the only update made was the distinction between workers not working and workers telecommuting described above, which affected the telecommute rate estimation from model runs as well as the telecommute assumption used in future (No Project) model years.

54 https://mtc.ca.gov/our-work/plans-projects/other-plans/bay-area-transportation-study.

Several transportation strategies comprised of programmatic expenditures on projects exempt from air quality conformity analysis, such as state of good repair investments or transit stop improvements, were not evaluated in the travel model. This affected the following strategies:

- **Strategy T1:** Restore, Operate and Maintain the Existing Transportation System: the only modeled component of this strategy was the restoration of transit headways to baseline levels in the Plan after 2030 from the reduced service levels described in the Transit Network section above.
- **Strategy T2:** Support Community-Led Transportation Enhancements in Equity Priority Communities: the specific projects that would be funded under this strategy would be defined later, through a collaborative process allowing residents of Equity Priority Communities to prioritize projects. Existing community-engaged planning work at MTC and ABAG suggests that community recommendations would likely focus on improvements that do not increase transit or road capacity, such as bus shelters, sidewalk improvements or traveler information services. As such, this strategy was not modeled.
- **Strategy T7:** Advance Other Regional Programs and Local Priorities: in general, investments nested within this strategy include improvements to local streets not represented within the travel model network or ongoing programs that do not increase capacity on roads or transit systems. As such, this strategy was not modeled.

Strategy T3 | Enable a Seamless Mobility Experience

The goal of this strategy is to reduce the friction of taking multi-operator or multi-modal trips. It encompasses several different elements, such as a smartphone app for trip planning and payment, real-time passenger information, wayfinding signage and cross-operator schedule coordination. The modeling approach focuses on the cross-operator schedule coordination element.

Cross-operator schedule coordination is expected to be implemented in 15 strategic locations (see Figure 30). In the model, a maximum transfer time was applied at these locations (i.e., transit nodes in modeling terminology). The transit nodes are classified as either a regional-to-regional node or a regional-to-local node. Regional-to-regional nodes are given a maximum transfer time of 3 minutes, whereas regional-to-local nodes are given a maximum transfer time of 5 min (see summary in Table 38 below).

Transfer time is one of the travel time components in the mode choice model. Reduced transfer times make transit a more attractive choice to travelers. In TM1.5, the model coefficient for transfer time is twice the magnitude of the model coefficient for in-vehicle time, to represent travelers' perception that a minute spent on transferring is more onerous than a minute spent sitting in a vehicle.

Figure 30. Seamless nodes

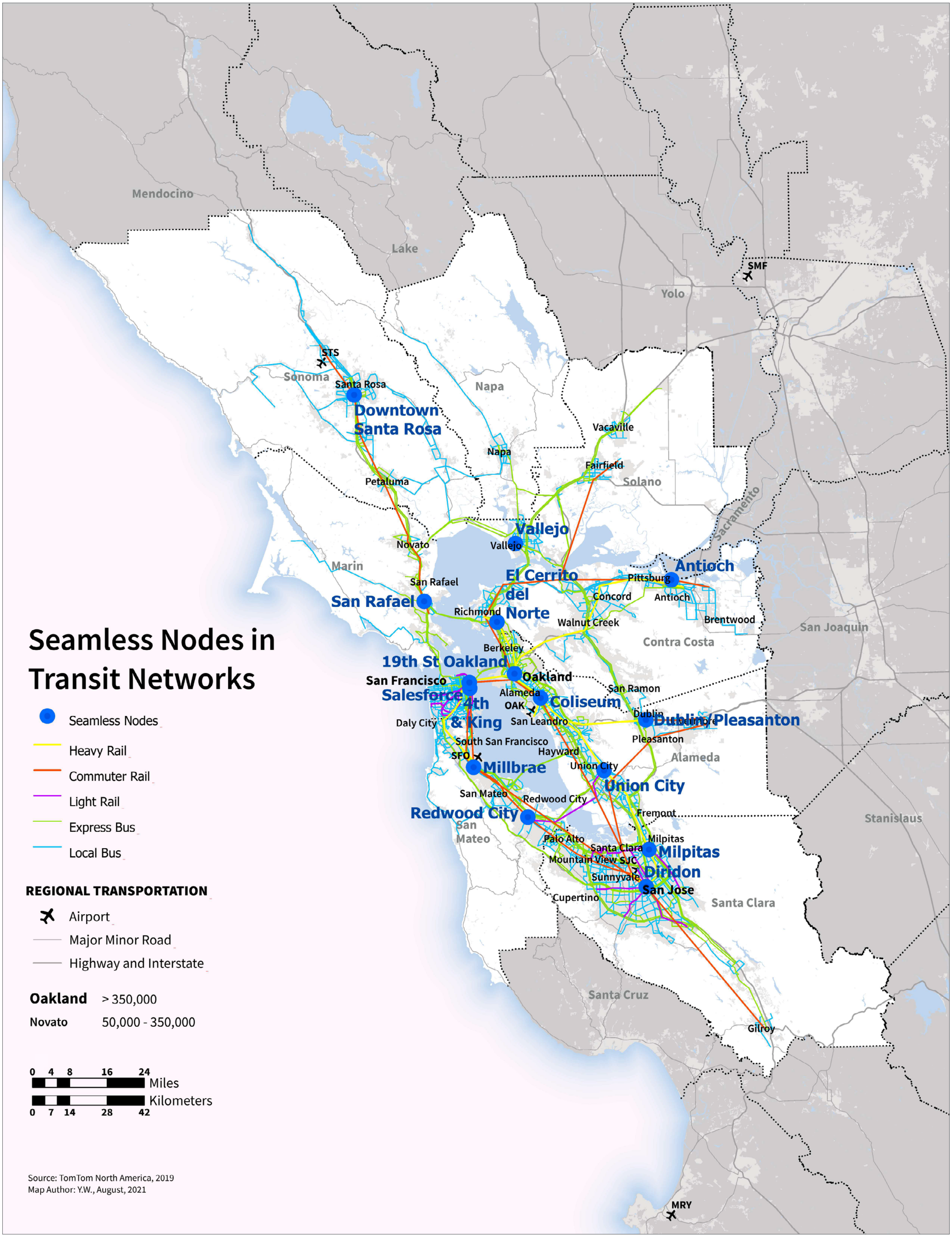


Table 38. Maximum transfer time at seamless nodes

CLASSIFICATION	TRANSIT NODE	TRANSIT SERVICE
Regional-to-local node (maximum transfer time = 5 minutes)	19th St Oakland	BART ↔ ReX, BRT
	4th and King	Caltrain ↔ Muni
	Antioch	BART ↔ BRT
	Diridon	Caltrain ↔ BART, ReX, VTA
	Downtown Santa Rosa	SMART ↔ Bus
	Milpitas	BART ↔ VTA
	Salesforce	Caltrain ↔ Muni
	Vallejo	ReX ↔ Bus
Regional-to-regional node (maximum transfer time = 3 minutes)	Coliseum	BART ↔ Bus
	Dublin/Pleasanton	BART ↔ Valley Link
	El Cerrito del Norte	BART ↔ ReX
	Millbrae	Caltrain ↔ BART
	Redwood City	Caltrain ↔ ReX, Dumbarton
	San Rafael	SMART ↔ Bus
	Union City	BART ↔ Dumbarton

Strategy T4 | Reform Regional Transit Fare Policy

The regional transit fare reform has two parts: (i) a streamlined fare structures across the region's 27 transit operators and replace existing operator-specific discount fare programs with an integrated fare structure across all transit operators; and (ii) a means-based fare discount for low-income riders.

Regional transit fare reform was implemented in Travel Model 1.5 by effectively overriding the fares calculated by the normal methods. During the normal course of a travel model run, fares are calculated from a variety of methods, including flat, operator-based fares; stop-to-stop based fares for some operators (such as BART and Caltrain); transfer fares and discounts, etc. To represent a regional integrated fare structure, these fares were calculated normally, but then swapped out with an integrated fare structure before being used by the travel model core, where simulated travelers make decisions about their travel. The integrated fares included were as follows: for travelers who used only local buses (including light rail), a flat fare of $2.55 (in 2020 dollars) was assumed. For travelers who used other modes (ferry, express bus, commuter rail or heavy rail), a fare was assumed based upon the total distance traveled on transit.

Table 39. Reform Regional Transit Fare Policy assumptions for distance-based regional transit fares

DISTANCE TRAVELED	FARE (IN 2020 DOLLARS)	FARE (IN 2000 DOLLARS)
0-10 miles	$3.62	$2.17
10-20 miles	$4.68	$2.80
20-30 miles	$5.71	$3.42
30-40 miles	$6.75	$4.04
40-50 miles	$7.78	$4.66
Over 50 miles	$8.82	$5.28

A means-based fare discount of 50% was given in the model to individuals in households with annual incomes less than $30,000 (in 2000$). Modeling of this discount was implemented through a simple change in the fare input to the mode choice component, in which lower fares make transit a more attractive choice to low-income travelers.

While the means-based fare discount is reflected in the mode choice component of TM1.5, it is not reflected in the transit route choice component of the model. This is because the transit assignment component of TM1.5 does not have income segmentation. Adding income segmentation to the transit assignment component would require a significant level of effort to upgrade the model. More importantly, adding income segmentation to transit assignment would greatly increase model run time. Given these resource constraints and potential run time issues, MTC staff decided not to pursue such an upgrade. This means discounted fares would not be a factor affecting transit route choice in the model, but MTC staff judged this a minor caveat that would not have a significant impact on the modeling results – especially since all operators/routes would have the same discount level.

This strategy was modeled consistently across the Plan and EIR Alternatives with one key exception. In EIR Alternative 2, the means-based fare discount was extended to passengers with a household income in quantile 2 (under $100,000 in 2020 dollars) to better advance equity outcomes.

Strategy T5 | Implement Means-Based Per-Mile Tolling on Congested Freeways with Transit Alternatives

This strategy involves implementing a per-mile charge on auto travel on congested freeway corridors where transit alternatives exist (BART, Caltrain, SMART, Valley Link, VTA Light Rail, and Regional Express Bus). Drivers on these corridors would pay a higher charge during the morning and evening peak periods, with discounts for off-peak travel, carpools with three or more occupants, or travelers with a qualifying disability (although disability is not modeled). Toll rates would be 15 cents per mile (9.3 cents per mile in 2000$) for solo travel in the morning (6am to 10am) and afternoon (3pm to 7pm) peak periods and 5 cents per mile (3.1 cents per mile in 2000$) for travelers in discount categories above. To support equity goals and reduce the potentially regressive impact of this pricing measure, lower-income drivers (i.e., those in households with annual income lower than $100,000 in 2020$, or $60,000 in 2000$) would be charged only half of the per-mile tolling rate. Bridge tolls would remain in effect, with no per-mile toll on the bridges. Existing express lanes on corridors without a transit alternative would continue to operate, while existing express lanes on corridors with per-mile tolling would be converted to carpool lanes on an all-lane tolling corridor. Figure 28 shows a map of the per-mile tolling corridors in the Plan (and EIR Alternatives 1 and 2) in 2050 in red. The figure also shows other priced corridors, including other express lanes that would be tolled but not part of the per-mile tolling system and the SR-37 priced corridor which would be tolled to fund sea level rise adaptation measures.

Strategy T6 | Improve Interchanges and Address Highway Bottlenecks

This strategy includes a set of capacity expansions or operational improvements on highway corridors and at interchanges throughout the region. This includes improvements at key regional interchanges like the I-80/I-680/SR-12 interchange in Solano County, the I-680/SR-4 interchange in Contra Costa County, and more. Widenings are highly limited and include the widening of SR-4, the construction of a new connector facility between SR-4 and Byron Highway, and a direct connector between US-101 and I-580. The complete set of projects included in this strategy can be found in the Draft Plan Bay Area 2050 Transportation Project List.

The Plan and the EIR Alternatives included the same projects nested under this strategy, with a few key exceptions. For EIR Alternative 1, the following projects were removed to minimize environmental impacts:

- SR-37 Interim Project
- SR-37 Ultimate Project
- SR-262 Safety and Interchange Improvements | Phase 1
- I-680/SR-4 Interchange Improvements Phases 1, 2, 4 and 5
- SR-4 Operational Improvements (Eastbound and Westbound)
- Widening of SR-4 and Vasco Road
- US-101/I-580 Direct Connector
- I-80/I-680/SR-12 Interchange and Widening Phases 3-7
- Vasco Road Byron Highway Connector Road

Strategy T8 | Build a Complete Streets Network

This strategy involves enhancing streets to promote walking, biking, and other micro-mobility by (1) building out a contiguous regional network of 10,000 miles of bike lanes or multi-use paths; (2) providing support to local jurisdictions to maintain and expand car-free slow streets; and (3) supporting other amenities like improved lighting, safer intersections, and secure bike parking at transit stations. This strategy would emphasize Complete Streets improvements near transit to improve access and in Equity Priority Communities to advance equity outcomes (although the geographical aspect of this strategy is not clearly determined yet and is not modeled).

Travel Model 1.5 does not include a detailed bike and pedestrian network, and it is not designed to represent traveler responses to improvement in safety and comfort that may result from a Complete Streets network or expanded bike infrastructure. Therefore, to predict this strategy's potential impacts, staff estimated the effect of this strategy based on available literature and integrated this effect into the modeled mode choice.

Three research studies, Dill and Carr (2003), Marshall and Garrick (2010), and Buehler and Pucher (2011), were identified by CARB in the Final Sustainable Communities Strategy Program and Evaluation Guidelines Appendices (November 2019) as providing elasticities that can be used to determine the relationship between bike infrastructure supply (e.g., miles of bike lane per square mile of land, or miles of bike) and bike usage (e.g., percent commuting by bicycle). Based on GIS analysis, MTC staff determined that the Complete Streets Network strategy is expected to add 5,600 miles of new bicycle infrastructure between 2015–2035 and another 6,000 miles between 2036-2050. Given this input, staff used the relationships inferred from the three research studies cited above and calculated the expected mode shift. The expected impact on walking is not modeled, as the existing literature does not provide enough evidence to estimate these impacts.

The bicycle mode choice constant was increased to represent improvement in several unmeasured characteristics of the mode such as perceived safety, comfort and convenience resulting from the bike infrastructure expansion. Without the constant adjustment, the cycling mode share in the Plan would have been 2.6% in both 2035 and 2050. Based on literature-based estimates of increased bicycle-trip making, the bicycle mode choice constant was calibrated to result in a cycling mode share of approximately 4.6% and 7.0% in 2035 and 2050 respectively.

EIR Alternative 2 includes an additional reserve for pedestrian improvements, which was not modeled.

Strategy T9 | Advance Regional Vision Zero Policy through Street Design and Reduced Speeds

Travel Model 1.5 represents maximum roadway speeds based on a lookup using the area type and facility type of that link.[55] For example, a link with facility type of freeway would have a maximum speed of 65 mph in rural and suburban areas, 60 mph in urban areas, and 55 mph in central business districts (CBD) and the regional core.

To represent this strategy, the lookup was modified to reduce speed limits to between 20 and 35 mph on arterials and local streets, and 55 mph on freeways. The following table shows the relationship between area type, facility type and maximum speed, with and without this strategy. Note that the maximum speed reduction for freeways is assumed to be implemented in 2030, while the maximum speed reduction for major arterials is assumed to be implemented in 2025.

Table 40. Strategy to Advance Regional Vision Zero Policy, speed reductions by facility type and area type

<table>
<tr><th>FACILITY TYPE</th><th>AREA TYPE</th><th>MAXIMUM SPEED, BEFORE STRATEGY</th><th>MAXIMUM SPEED, WITH STRATEGY</th></tr>
<tr><td rowspan="3">Freeway</td><td>Urban Business</td><td>60 mph</td><td rowspan="3">55 mph</td></tr>
<tr><td>Urban</td><td>60 mph</td></tr>
<tr><td>Suburban, Rural</td><td>65 mph</td></tr>
<tr><td rowspan="5">Major Arterial</td><td>CBD</td><td>25 mph</td><td>20 mph</td></tr>
<tr><td>Urban Business</td><td>30 mph</td><td>20 mph</td></tr>
<tr><td>Urban</td><td>30 mph</td><td>25 mph</td></tr>
<tr><td>Suburban</td><td>35 mph</td><td>30 mph</td></tr>
<tr><td>Rural</td><td>40 mph</td><td>35 mph</td></tr>
</table>

Strategy T10 | Enhance Local Transit Frequency, Capacity and Reliability

Projects within this strategy aim to make local bus and light rail service faster and more frequent. Network frequency boosts on AC Transit, Muni, Sonoma County Transit and more provide a more frequent baseline on some of the region's highest ridership routes. Additionally, capital projects that increase the speed and reliability of transit maximize the throughput of existing service. Example projects include light rail grade separation in downtown San Jose, BRTs on Geary Boulevard and San Pablo Avenue, and transit signal priority in Napa, among others.

Cordon Tolls

Two cordon tolls are also part of this strategy. The Plan, as well as EIR Alternatives 1 and 2, include two cordon tolls: one in downtown San Francisco, and another on Treasure Island. The downtown San Francisco scheme, which is expected to be implemented in 2025 in the Plan, requires all vehicles to pay a $6 (in 2010$, which is $7.92 in 2020$ or $4.76 in 2000$) fee to enter or leave the greater downtown San Francisco area during the evening commute period. The cordoned area is bounded by Laguna and Guerrero Streets to the west, 18th Street to the south, and San Francisco Bay to the north and east.

55 For more on Facility Type and Area Type definitions, see https://github.com/BayAreaMetro/modeling-website/wiki/MasterNetworkLookupTables#facility-type-ft.

The Treasure Island cordon toll, which is expected to be implemented in 2035 in the Plan, is set at $5 in 2021$ (which is $4.93 in 2020$ or $2.99 in 2000$) during the morning and afternoon peak, $1.50 in 2021$ (which is $1.48 in 2020$ or $0.89 in 2000$) in midday. There is not expected to be a toll in the evenings and early mornings.
The toll is charged to all vehicles entering Treasure Island from I-80 in either the westbound or eastbound direction.

Local Transit Projects

The Plan and the EIR Alternatives included the same projects nested under this strategy, with a few key exceptions.

EIR Alternative 1 further improves local transit frequencies to encourage mode shift away from driving, focusing on core bus service that was overcrowded in the Plan. This includes doubling the peak frequency of select routes on AC Transit local bus service, Muni local bus service and VTA local bus service. EIR Alternative 1 also includes a reserve for transit signal priority capital improvements, which was not modeled.

EIR Alternative 2 also improves local transit service beyond the Plan investments. The VTA Orange Line serving northern Santa Clara County receives a frequency boost to better serve jobs-rich Growth Geographies. There is also a reserve for grade separations on this line that is not modeled. Across the region, all Growth Geographies not adjacent to rail, ferry or bus service with peak headways of 15 minutes or greater see local bus frequency upgrades. Jobs-rich Growth Geographies that were identified for more intensive development in EIR Alternative 2 see even greater investments in local transit service to align with projected growth.

Strategy T11 | Expand and Modernize the Regional Rail Network

Investments nested under this strategy include key extensions to existing rail networks, including the extension of BART to downtown San Jose, the Caltrain Downtown Extension and Valley Link, among others. Additionally, a new rail link between downtown Oakland and downtown San Francisco provides additional capacity to the transbay corridor. These extensions are complemented by modernization projects that increase frequencies on rail networks, including South Bay Connect, improving Capitol Corridor service in Alameda County, BART Core Capacity, and projects boosting ACE and Caltrain frequencies. Ferry projects are also nested within this strategy, including new service to Berkeley, the Seaplane Lagoon in Alameda, Redwood City, and more. The full list of projects included in this strategy can be found in the Plan Bay Area 2050 Transportation Project List.

The Plan and the EIR Alternatives included the same projects nested under this strategy, with a few key exceptions. For EIR Alternative 2, regional rail projects are delayed one period to free up fiscal capacity for local transit improvements. The following projects are delayed to open after 2035 in EIR Alternative 2:

- Caltrain Downtown Extension
- South Bay Connect
- Valley Link

The following projects open after the year 2035 in the Plan. In EIR Alternative 2, they are delayed to open after 2050, meaning they are not modeled:

- Caltrain/High-Speed Rail Electrification and Grade Separation: Tamien to Pacheco Pass
- Dumbarton Group Rapid Transit
- Link21 New Transbay Rail Crossing

Strategy T12 | Build an Integrated Regional Express Lanes and Express Bus Network

To maximize the time-competitiveness of express bus and carpool trips in comparison to single-occupancy vehicles, this strategy includes a full build-out of the express lanes network, the introduction of new express bus routes throughout the region, and frequency increases on select existing express bus service. The full list of projects included in this strategy can be found in the Draft Plan Bay Area 2050 Transportation Project List.

The Plan and the EIR Alternatives included the same projects nested under this strategy, with a few key exceptions. For EIR Alternative 1, all express lanes projects that required the construction of a new lane were modified to instead convert a lane of general purpose travel to an express lane, except for the proposed express lane on SR-85, where there are only two lanes of travel in either direction. Staff determined that converting this facility to have just a single lane for general purpose travel was not feasible.

In EIR Alternative 2, the Plan project list is modified to include additional capital improvements and frequency boosts on AC Transit transbay routes; add express bus service along I-580 in eastern Alameda County prior to the delayed opening of Valley Link in model year 2040; to improve frequencies on ReX Green Line and Blue Line; and to implement capital upgrades to ReX Blue Line stations to provide a premium service.

Strategy EN1 | Adapt to Sea Level Rise

The plan assumes a future with two feet of sea level rise by 2050. To reduce the impact of associated inundation, the Plan, EIR Alternative 1 and EIR Alternative 2 include efforts to mitigate sea level rise by addressing adaptation needs. Protective measures are funded in most locations that are permanently inundated. Equity Priority Communities and areas with high benefit and low cost are prioritized for protection. In the No Project alternative, mitigation is much more limited; only committed mitigation project locations are protected from sea level rise. The committed mitigation projects are: San Francisco Airport Shoreline Protection Program, Foster City Levee Project, South Bay Shoreline Project, and Oakland Airport Sea Level Rise Adaptation.

This degree of sea level rise would inundate several major rail and highway corridors, removing them from the travel model network. One component of this strategy is to prevent inundation from sea level rise on SR-37, segments of US-101 on the Peninsula and in the North Bay, I-580 in Marin County, and other key facilities.

The Plan and the EIR Alternatives included the same projects nested under this strategy, with a few key exceptions. For EIR Alternative 1, the SR-37 Ultimate Project — which includes additional highway capacity and contributes to the project footprint — was removed to minimize environmental impacts, resulting in inundation and removal from the model network.

Table 41 shows the impacts of sea level rise for each alternative, listing affected alternatives and the level of future protection. The inundation levels are assumed to be 12 inches by 2035 and 24 inches by 2050, which affect mostly the No Project alternative because the other alternatives assume some inundation protection. Bus bridges were created to fill the gap between transit stations in the No Project alternative, including the following:

- between Fremont and San Jose Diridon serving Capitol Corridor,
- between Martinez and Suisun City serving the Capitol Corridor, and
- between the Marin Civic Center and downtown Petaluma stations, serving SMART.

Additionally, Tasman station is closed for VTA light rail; as a result, the Blue and Green lines stop at River Oaks, while the Orange line bypasses Tasman. All other alternatives have protection measures that will mitigate inundation through 2050, except for SR-37 which floods in EIR Alternative 1.

Table 41. Impact of sea level rise by alternative

CORRIDOR	COUNTY	FROM	TO	NO PROJECT		PLAN	EIR ALTERNATIVE 1	EIR ALTERNATIVE 2
				2035	2050			
US-101	MRN	Sir Francis Drake Blvd.	Tamalpais Drive Interchange	×	×	✓	✓	✓
I-580	MRN	Bellam Blvd.	Sir Francis Drake Blvd.	×	×	✓	✓	✓
SR-37	MRN, NAP, SOL, SON	US-101 Interchange	Mare Island Interchange	×	×	✓	×	✓
US-101	MRN	Bellam Blvd.	2nd St.	×	×	✓	✓	✓
Seaport Blvd.	SM	US-101	(Entire Road)	✓	×	✓	✓	✓
University Ave.	SM	O'Brien Dr.	Bayfront Expy.	✓	×	✓	✓	✓
N Mathilda Ave.	SCL	Lockheed Martin Way	W Caribbean Dr.	✓	×	✓	✓	✓
E Caribbean Dr.	SCL	Borregas Ave.	N Mathilda Ave.	✓	×	✓	✓	✓
Union City Blvd.	ALA	Smith St.	Alvarado Blvd.	✓	×	✓	✓	✓
Doolittle Dr.	ALA	Bay Farm Island Bridge	OAK and Island Dr.	✓	×	✓	✓	✓
Webster/ Posey Tubes	ALA	City of Alameda		✓	×	✓	✓	✓
Lakeville Hwy.	SON	Gate 9	SR-37	×	×	✓	✓	✓
Irwin St.	MRN	US-101	Woodland Ave.	×	×	✓	✓	✓
Shoreline Hwy.	MRN	Pohono St.	Almonte Blvd. and US-101	×	×	✓	✓	✓
Shoreline Hwy.	MRN	Van Pragg	Stinson Beach	×	×	✓	✓	✓
ACE	ALA, SCL	Fremont	San Jose	×	×	✓	✓	✓
Capitol Corridor	ALA, SCL	Fremont	San Jose	×	×	✓	✓	✓

CORRIDOR	COUNTY	FROM	TO	NO PROJECT		PLAN	EIR ALTERNATIVE 1	EIR ALTERNATIVE 2
				2035	2050			
Capitol Corridor	CC, SOL	Martinez	Suisun City	×	×	✓	✓	✓
Ferries	ALA, SF	San Francisco	Alameda/ Oakland	✓	×	✓	✓	✓
Ferries	ALA, SM	South San Francisco	Alameda/ Oakland	✓	×	✓	✓	✓
SMART	MRN, SON	Marin Civic Center	Downtown Petaluma	×	×	✓	✓	✓
VTA LRT	SCL	Tasman Station		×	×	✓	✓	✓

NOTE: a check mark (✓) indicates the facility was protected from inundation and an x (×) indicates the facility was inundated. Plan Bay Area 2050 assumes 1 foot of sea level rise by 2035 and 2 feet of sea level rise by 2050.

Strategy EN7 | Expand Commute Trip Reduction Programs at Major Employers

This strategy entailed setting a sustainable commute target for all major employers, such that by the year 2035, no more than 40% of each employer's workforce would be eligible to commute by auto on an average workday. To represent the effects of this strategy in Travel Model 1.5, staff first estimated the effects of this strategy on the modeled workforce. This was done using the following steps:

1. Starting with National Establishment Time Series (NETS) dataset which includes establishment, establishment sizes and industry, staff filtered to the 2015 establishments in the Bay Area counties
2. This dataset was then joined with firm data (also from the NETS dataset) based on the headquarters ID to segment the workforce into large firms and exclude small businesses, which would not be affected by the strategy.
3. Each establishment corresponds to one industry (for example, NAICS 54110, Legal Services), but that industry consists of a mix of occupations (for example, Lawyers and Judicial Law Clerks, Computer Support Specialists, Human Resources Workers, Building Cleaning Workers, etc). Using the May 2019 National Industry-Specific Occupational Employment and Wage Estimates[56], worker tallies by industry were translated to worker tallies by occupation.
4. Each occupation was assumed to be able to telework based a crosswalk from Dingel's and Neiman's research.[57]
5. Combining the above steps, maximum telecommute rates were developed for employment in each Bay Area county based on the forecasted employment for that county by industry category. Note that staff do not forecast firm sizes, so the percentage of employees excluded due to small firm size in 2015 was carried forward into future years.

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56 May 2019 National Industry-Specific Occupational Employment and Wage Estimates: https://www.bls.gov/oes/current/oessrci.htm.

57 Jonathan I. Dingel & Brent Neiman, 2020. "How many jobs can be done at home?," Journal of Public Economics, vol 189.

Using the maximum telecommute rates, staff then calibrated a telecommute constant for each employment super district using the following logic: If the commute tour auto mode share for the super district was already less than the 40% target, then no additional telecommuting was modeled beyond the baseline estimate described in the section on . If the commute tour auto mode share to the super district exceeded 40%, the telecommute constant was calibrated upwards until telecommuting approached the maximum rates described above. As staff strived to be conservative about strategy benefits, note that this resulted in many workplace super districts continuing to exceed their 40% commute mode share target. Staff assumes that many of these workplaces would institute other measures to shift workers to alternative modes to reach their targets, but these are not captured in the model. Therefore, this representation likely underestimates the effect of this strategy on travel.

Strategy EN9 | Expand Transportation Demand Management Initiatives

This strategy included several components, most of which were not represented in the Travel Model. The analysis for these initiatives is described in the Off-Model Calculations section following. However, this strategy also included a parking pricing component, which was implemented in Travel Model 1.5.

As described in the above section on Parking Prices, Travel Model 1.5 represents parking pricing based on the tour and trip destination's travel analysis zone (TAZ), as well as the tour and trip purpose and the activity duration. Additionally, Travel Model 1.5 includes a simple Free Parking model to capture the fact that some employers subsidize employee parking even in areas with non-zero long term parking pricing.

In order to model the parking pricing component of this strategy, staff expanded the set of TAZs with non-zero parking pricing, assuming that TAZs within the Growth Geographies would have a minimum hourly cost (both for long-term and for short-term parking) of $0.25 per hour (in 2000 dollars), thereby expanding the set of TAZs with non-zero parking pricing.[58] Additionally, staff assumed a parking price increase of 25% above the No Project hourly cost for all TAZs within both Growth Geographies and Transit Rich Areas. Since Travel Model 1.5 TAZs do not match well with Growth Geographies and Transit Rich Areas, qualified TAZs were determined using a threshold approach, where a TAZ was defined as being "within" the relevant geography if 20% or more of the TAZ area intersected with the geography. Finally, this strategy assumed that employer subsidy of employee parking costs has been disallowed, and the Free Parking model was disabled.

Off-Model Calculations

Travel Model 1.5 is not sensitive to the full range of policies MTC and ABAG may choose to pursue in Plan Bay Area 2050. Marketing and education campaigns, as well as non-capacity-increasing transportation investments like bikeshare programs, are examples of strategies with the potential to change behavior in ways that result in reduced vehicle emissions. Travel Model 1.5 and EMFAC do not estimate reductions in emissions in response to these types of changes in traveler behavior. As such, MTC and ABAG use "off-model" approaches to quantify the GHG reduction benefits of these important programs.

Nested under strategies EN8 and EN9, the Climate Initiatives Program (CIP) includes a variety of off-model strategies to complement the development patterns and transportation investments identified in Plan Bay Area 2050. The CIP's primary objective is to invest in strategies that reduce transportation-related GHG emissions by reducing per-capita vehicle miles traveled (VMT) through more fuel-efficient vehicles and sustainable travel behavior. In broad terms, the CIP focuses efforts in two categories: 1) transportation demand management, and 2) clean vehicle incentives and infrastructure.

58 The Plan Bay Area 2050 Growth Geographies are locations prioritized for future jobs and housing growth. For more information, refer to the Draft Plan Bay Area 2050 Plan Document.

The following off-model strategies are included in Plan Bay Area 2050:

- Bike Share
- Car Share
- Targeted Transportation Alternatives
- Vanpools
- Regional Electric Vehicle Chargers
- Vehicle Buyback & Electric Vehicle Incentives

All of these strategies were included in the previous regional plan, Plan Bay Area 2040, and the primary GHG emission calculation approaches remain unchanged. However, the calculation inputs and assumptions have been updated to reflect new data and research, where available, and travel model outputs reflecting the Plan Bay Area 2050 Plan scenario. The strategy descriptions, GHG emission quantification approaches, and results are summarized in the following section by strategy.[59]

Bike Share

Bike share systems provide bicycles that members of the public can borrow and use for limited durations in exchange for a fee. In traditional systems, bike share bicycles must be borrowed from and returned to designated docking stations. More recently, dockless bike share systems have emerged, allowing users to leave the bicycles anywhere in the service area. Additionally, bike share providers offer electric bikes, or e-bikes, that can be both parked at a station or elsewhere. Dockless e-bikes may attract more users and replace more motorized vehicle trips by making bike trips more convenient and by expanding the trip distances that can be made by bike share. In an analysis of docked, dockless, and e-bike bike share services in San Francisco, researchers found that a dockless e-bike service was used for more bike trips per bike and for longer trips.[60]

In August 2013, in collaboration with MTC, the Bay Area Air Quality Management District implemented a bike share system in the Bay Area on a limited pilot basis called Bay Area Bike Share (BABS). BABS consisted of approximately 700 bikes deployed across 70 stations; approximately half in San Francisco and the other half in South Bay cities. This pilot program provided valuable information regarding the potential for bike share systems to reduce VMT and emissions.

Since the initial pilot program, bike share has expanded widely across the Bay Area both in the number of bikes and in the number of service areas. The system, now called Bay Wheels, is growing to 7,000 bikes and operates across San Francisco, Berkeley, Emeryville, Oakland, and San Jose. Lyft owns and operates the system with MTC serving as contract administrator. MTC has also provided grants to initiate other bike share services that will expand access in the East Bay and bring bike share to the counties of Marin and Sonoma along the SMART train corridor. MTC also manages the Clipper Card, which can also be used to access and unlock bike share bikes.

GHG Reduction Quantification Approach

Bike share reduces GHG emissions by enabling users to take short-distance trips by bicycle instead of by car, and in some cases bike share can eliminate longer trips by enabling users to connect to transit. Bike share program expansion is not captured in MTC's travel model. The mode choice models in Travel Model 1.5 were calibrated using the California Household Travel Survey from 2012-2013, before bikeshare deployment. Although MTC's travel model includes bicycling as a travel mode, it is not structured to capture the travel effects of expansion of a bike share system.

In Plan Bay Area 2040, bike share ridership was estimated based on studies of other systems. For Plan Bay Area 2050, the approach has been updated to incorporate recent ridership data collected from the regional bike share operator. Additionally, the approach now includes modeling the impacts of the rapid introduction of e-bikes into the regional bike share system.

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59 Note that the off-model analysis results for the No Project alternative are not shown. Off-model strategies are excluded in the No Project alternative and thus result in zero GHG emission reductions.

60 Lazarus, Jessica, Jean Carpentier Pourquier, Frank Feng, Henry Hammel, and Susan Shaheen. Bikesharing Evolution and Expansion: Understanding How Docked and Dockless Models Complement and Compete--A Case Study of San Francisco. No. 19-02761. 2019.

Inputs and Assumptions

Travel and emissions impacts are calculated based on the number of Bay Wheels bike share trips and the relationship between bike share trips and VMT reduction.

Lyft reported the number of trips using the Bay Wheels system for the period May to October 2019, shown in the table below. The daily average during this period is 7,089 trips per day.

Table 42. Bike share trips using Bay Wheels system, 2019

CITY	MAY	JUNE	JULY	AUG	SEPT	OCT
Berkeley	15,854	14,173	12,738	17,985	20,324	20,307
Emeryville	1,795	1,989	1,916	2,159	2,071	1,987
Oakland	21,310	22,286	38,145	24,395	24,003	23,723
San Francisco	132,452	142,594	189,313	156,762	160,512	182,369
San Jose	10,945	12,355	17,142	9,416	11,444	11,847
Monthly Total	182,356	193,397	259,254	210,717	218,354	240,233

During this same period, there were 3,203 Bay Wheels bicycles available per day. Full deployment of the bike share system will consist of 7,000 bicycles, including 4,500 in San Francisco, 1,500 in the East Bay, and 1,000 in San Jose. Usage of the system is expected to grow in proportion of the number of bicycles available. Once the system is fully deployed, use of the bike share system is expected to grow in proportion to population; this is a conservative assumption that does not account for expansion of bike share service beyond the planned Bay Wheels program, including service provided by other private providers and service funded through more recent MTC bike share grants.

The bike share trips were then converted to VMT reductions based on results from MTC's evaluation of the Bay Area Bike Share program, which found that each bike share trip, using conventional bicycles, reduced an average of 1.3 VMT.[61] Many bike share trips do not reduce any VMT because they do not displace vehicle trips, while others only reduce short trips, but the evaluation found that a significant share of bike share trips enables users to connect to transit, eliminating longer personal vehicle trips.

Over the last several years, bike share systems have begun transitioning to electric bicycles, which are popular with users and enable longer trips. In early 2020, only about 5% of Bay Wheels bicycles were electric, but the system is expected to continue the transition to electric over the next several years. By 2035, it is assumed that all bike share bicycles will electric.

Based on bike share system research conducted in the Bay Area, trips using dockless electric bicycles were 36% longer than trips using conventional bike share bicycles.[62] Using e-bikes, it is assumed that the VMT reduced per bike share trip will be 36% higher than the 1.3 VMT observed during the BABS pilot.

61 MTC Climate Initiatives Program Evaluation: Pilot Bike-sharing Program, Prepared for MTC by Eisen-Letunic, 2015.

62 Lazarus, Jessica, Jean Carpentier Pourquier, Frank Feng, Henry Hammel, and Susan Shaheen. Bikesharing Evolution and Expansion: Understanding How Docked and Dockless Models Complement and Compete--A Case Study of San Francisco. No. 19-02761. 2019.

Table 43. Inputs and assumptions for bike share calculations

PARAMETER	VALUE	SOURCE
Planned bike share bike availability (Bay Wheels)	7,000	MTC
Daily bike share trips	15,492	May-October 2019 bike availability and trips, Lyft Bay Wheels System Data
Average VMT displaced per conventional bike share trip	1.30	MTC Climate Initiatives Program Evaluation: Pilot Bike-sharing Program, 2015.
Average VMT displaced per e-bike share trip	1.77	Calculated based on Lazarus, J. et al. Bikesharing Evolution and Expansion: Understanding How Docked and Dockless Models Complement and Compete – A Case Study of San Francisco, Paper No. 19-02761. 2019.
Assumed share of e-bikes in bike share fleet, 2035 and 2050	100%	Assumption based on market trends

Calculation Methodology

The methodology for calculating the GHG reductions from the bike share strategy is as follows:

1. Calculate or obtain average bike share trips per day for base year.
2. Calculate percentage growth of Bay Area total population relative to base year.
3. Multiply the percentage population growth by the baseline average daily bike share trips to calculate the average daily bike share trips for modeled years.
4. Multiply the percentage share of e-bikes by the average bike share trips per day to calculate the number of conventional versus e-bike share trips per day for each modeled year.
5. Multiply the average VMT displaced per conventional bike share trip by the number of conventional bike share trips per day for each modeled year.
6. Multiply the average VMT displaced per e-bike share trip by the number of e-bike share trips per day for each modeled year.
7. Sum the VMT displaced by conventional bike share and e-bike share trips per day.
8. Multiply daily VMT displaced by exhaust emission rates to calculate GHG emission reductions.

Results

The table below summarizes the CO_2 reductions due to bike share.

Table 44. CO_2 emissions reductions due to bike share

ALTERNATIVE	DAILY REDUCTION (SHORT TONS)		PER CAPITA REDUCTION FROM YEAR 2005 EMISSIONS (PERCENT)	
	Year 2035	Year 2050	Year 2035	Year 2050
Plan	-15	-17	-0.02%	-0.02%
EIR Alternative 1	-15	-17	-0.02%	-0.02%
EIR Alternative 2	-15	-17	-0.02%	-0.02%

Car Share

Car sharing offers individuals the opportunity to conveniently rent vehicles by the hour or less, thus giving them access to an automobile without the costs (vehicle purchase, operations and maintenance, insurance) and responsibilities of personal vehicle ownership. Car sharing offers the opportunity for users to replace making trips in their own vehicles, particularly short trips such as for errands, shopping, or airport pick-ups. Car sharing can be particularly effective in neighborhoods with bus, rail, bike share, or other alternatives to driving where cars are infrequently needed and households in these neighborhoods can shed one or more vehicles. Even in less dense neighborhoods without high-quality alternatives to driving, car sharing can allow a two- or three-car household to shed one car by making a vehicle accessible for the infrequent instances that multiple vehicles are needed at the same time. Car sharing may also help extend the trend of younger generations putting off or never owning a vehicle. Businesses can also sign up for business memberships (known as corporate car sharing) to avoid maintaining or reduce the size of a company fleet of vehicles.[63]

Car sharing has been growing in the Bay Area since 2001, with multiple car share operators offering different service models, including traditional car share requiring pick-up and return of a company-owned vehicle at a specific location (e.g., Zipcar) and one-way or free-floating car share (e.g., Gig). Traditional car sharing businesses typically operate on a membership basis, where users pay an annual fee in addition to hourly and sometimes per-mile rates. Users benefit by not having to worry about fueling, maintenance, parking, and insurance, which are included in the membership and usage rates.

One-way car sharing allows a driver to pick up a vehicle in one location and drop it off at another, either at a specific location or anywhere within a service zone. This model provides an opportunity to incorporate driving as part of a longer multimodal trip chain. For example, Gig Car Share partnered with Bay Area Rapid Transit (BART) to provide designated Gig parking spaces at six BART stations, allowing users to drive a Gig car to transit, or alternatively, drive home after arriving at the station. This model also allows for more frequent vehicle turnover and higher utilization of vehicles, as the cars are rented just to get to destinations rather than rented and parked while the user completes their activities at the destination before returning the vehicle.

63 Reed, John. 2017. Corporate Car Sharing: an innovative solution to save the cost for company employee' car and taxi work travel. https://www.sharedmobility.news/corporate-car-sharing/.

The expansion of car sharing helps reduce GHG emissions by both reducing the amount participants drive and by shifting their driving to more fuel-efficient vehicles. The cumulative effect of car sharing, from a study conducted by UC Berkeley's Transportation Sustainability Research Center, found that for each car share vehicle, nine to 13 privately owned vehicles are shed from the region's vehicle fleet.[64] Vehicle owners drive more than those who do not own their own vehicle. Additionally, car share vehicles are newer and more fuel efficient than the average vehicle and thus contribute fewer emissions.

Car sharing was included in the previous regional plans and MTC will continue implementing relevant programs. Six grants were awarded to the following agencies to implement car sharing services:

- Contra Costa Transportation Authority
- Sonoma County Transportation Authority
- City of San Mateo
- City of Oakland
- City of Hayward
- Transportation Authority of Marin

Additionally, MTC is implementing a program for mobility hubs which will include car sharing as well as other shared transportation modes. Work has started on pilot projects with full implementation to follow.

GHG Reduction Quantification Approach

Car sharing is not explicitly captured in MTC's travel model, and a car share expansion strategy accordingly is accounted for off-model. Car sharing reduces emissions in two primary ways — by lowering the average VMT of members and by allowing trips to be taken with more fuel-efficient vehicles than would have been used without car sharing.

The primary calculation approach remains unchanged from Plan Bay Area 2040, estimating GHG reductions based on the reduced VMT and use of more fuel-efficient vehicles among car share program participants. However, the approach has been updated to reflect the increasing deployment of electric vehicles in car sharing fleets.

Inputs and Assumptions

Participation in the car share strategy is based on the number of Bay Area residents who are in the age groups likely to adopt car sharing and who live in communities that are compact enough to promote shared use. Research shows that adults between the ages of 20 and 64 are most likely to adopt car sharing, with estimates that between 10% and 13% of the eligible population in more compact areas adopt the practice when car sharing is available.[65, 66] With the implementation of regional strategies to support car sharing and the introduction of one-way car sharing, adoption rates are assumed to reach 14% of the eligible population in dense urban areas (i.e., areas with at least 10 people per residential acre) by 2035, while 3% of the eligible population could adopt car sharing by 2035 in suburban areas (i.e., areas with fewer than 10 people per residential acre). The table below summarizes the assumptions with respect to car sharing participation rates.

As one-way car sharing programs expand in the Bay Area, it is expected that participation in car sharing programs will increase. Recent research suggests that while one-way car sharing still reduces emissions, the reductions are not as large as with traditional car sharing, as discussed below. In this analysis, it is assumed that one-way car sharing comprises 20% of carshare members in 2020 and remains at this level for 2035 and 2050. The table below summarizes the participation assumptions.

64 Martin, Shaheen, and Lidicker, 2010, "Impact of Carsharing on Household Vehicle Holdings: Results from a North American Shared-Use Vehicle Survey." Transportation Research Record Volume 2143, Issue 1, Pages 150-158. URL: https://escholarship.org/uc/item/3bn9n6pq.

65 Zipcar. http://www.zipcar.com/is-it#greenbenefits. Accessed March 20, 2017.

66 Zhou, B., Kockelman, K, and Gao, R. "Opportunities for and Impacts of Carsharing: A Survey of the Austin, Texas Market." International Journal of Sustainable Transportation 5 (3): 135-152, 2011.

Table 45. Car share participation assumptions

CATEGORY	SCENARIO YEAR		
	2020	2035	2050
Participation rates in urban areas	12%	14%	14%
Participation rates in suburban areas	0%	3%	3%
Percent of car share members who participate in one-way car sharing programs	19%	20%	25%

Research by Robert Cervero indicates that on average traditional car share members drive seven fewer miles per day than non-members.[67] This is mostly due to the members who shed a vehicle after joining carsharing. Daily VMT of these car share members drops substantially and outweighs the increase in VMT from car share members that previously did not have access to a vehicle.

In addition to the reduction in VMT, when members drive in car share vehicles, their per-mile emissions are generally lower because car share vehicles are more fuel efficient than the average vehicle. Research by Martin and Shaheen found that the car share vehicles in their study used 29% less fuel per mile than the passenger vehicle fleet in general.[68] This reduction is used for year 2020 in this analysis and increases to 36% and 43% for 2035 and 2050, respectively, based on a conservative assumption of 10% to 20% of the car share fleet becoming fully electric. The same study also shows that on average, members of traditional car sharing programs drive an average of 1,200 miles in car sharing vehicles per year. MTC assumes this individual annual car share mileage will remain constant over time.

Martin and Shaheen conducted an analysis of one-way car share services in five cities across North America and estimated VMT reduction of participants.[69] Based on the study's findings, this approach assumes that one-way car share members drive an average of 104 miles in car sharing vehicles per year but overall drive 1.07 fewer miles per day than non-members. Also based on the study's findings, it is assumed that one-way car sharing fleets use 45% less fuel per mile. Furthermore, based on observed offerings from recent one-way car share providers, it is assumed that one-way car sharing service fleets will include a share of battery electric vehicles in future years. For this analysis, it is assumed that this mileage will remain constant over time.

67 Cervero, Golub, and Nee, "City CarShare: Longer-Term Travel-Demand and Car Ownership Impacts", July 2006, TRB 2007 Annual Meeting paper.

68 Martin, Elliot, and Susan Shaheen, "Greenhouse Gas Emission Impacts of Carshaing in North America," 2010, Mineta Transportation Institute. MTI Report 09-11.

69 Martin, Elliot, and Susan Shaheen, "Impacts of Car2Go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions", July 2016, Working Paper.

Table 46. Car share calculation inputs and assumptions

PARAMETER	VALUE	SOURCE
VMT per member per year, traditional carshare	1,200	Estimate based on Martin and Shaheen, MTI report, 2010 (figure 7); assume constant over time
VMT per member per year, one-way carshare	104	Martin and Shaheen, July 2016
VMT reduction per member per day, traditional car share	7	Cervero, Golub, and Nee, July 2006
VMT reduction per member per day, one-way car share	1.07	Martin and Shaheen, July 2016
Average mpg, traditional car share vehicles	32.8	Average US/Canada mpg from Martin and Shaheen, MTI report, page 65; assumed constant from 2010
Average mpg, one-way car share vehicles	24.4	Martin and Shaheen, July 2016
Average mpg, cars avoided by traditional car share service members	23.3	Average US/Canada mpg from Martin and Shaheen, MTI report, page 65; assumed constant from 2010
Average mpg, cars avoided by one-way car share service members	44.0	Martin and Shaheen, July 2016
Battery electric vehicle share of fleet, traditional car share	10% (2035); 20% (2050)	Assumption based on conservative electric vehicle adoption rate
Battery electric vehicle share of fleet, one-way car share	50%	Assumption based on current 100% electric one-way Gig car share fleet in Sacramento area
Travel days per year	347	Standard State Assumption

Calculation Methodology

To calculate the GHG emission reductions due to car sharing, the individual steps were as follows:

1. Calculate the residential density of each transportation analysis zone (TAZ) during the scenario year by dividing the total population by the residential acres (from travel demand model).
2. Sum total car sharing eligible population (between the ages of 20 and 64) for urban areas (TAZs with a population density greater than 10 residents per residential acre) and for suburban areas (TAZs with a population density less than 10 residents per residential acre).
3. Multiply participation rates, urban and suburban, by the car sharing eligible population in urban and suburban areas, respectively, and sum to calculate car share program members.
4. Multiply the one-way car share participation rate to calculate the number of members in traditional and one-way car sharing services.

Number of traditional (station-based) car share members	$= [P_{>10} \times QP_{urban} + P_{<10} \times QP_{suburban}] \times (1 - QP_{1-way})$
Number of one-way car share members	$= [P_{>10} \times QP_{urban} + P_{<10} \times QP_{suburban}] \times QP_{1-way}$
Number of one-way car share members	$= [P_{>10} \times QP_{urban} + P_{<10} \times QP_{suburban}] \times QP_{1-way}$

Where:

$P_{>10}$ = the total population in TAZs with density greater than 10 persons/residential acre

QP_{urban} = the percent of qualifying urban population expected to become members

$P_{>10}$ = the total population in TAZs with density less than 10 persons/residential acre

$QP_{suburban}$ = the percent of qualifying suburban population expected to become members

QP_{1-way} = the percent of car share members participating in one-way car share

5. Multiply the VMT reduced per day per member by the number of members of each service type and sum the result across both service types to calculate VMT reduction per day from car share users.

Total daily VMT reductions from car sharing members driving less	$= M_{trad} \times V_{trad} + M_{1-way} \times V_{1-way}$

Where:

M_{trad} = the number of traditional car share members

V_{trad} = the VMT reduction per traditional car share member per day

M_{1-way} = the number of one-way car share members

V_{1-way} = the VMT reduction per one-way car share member per day

6. Multiply daily VMT reductions by average vehicle emission rates from EMFAC2014 to calculate GHG emission reductions due to car share members driving less.
7. Multiply the number of car share members for traditional and one-way car sharing by the respective average VMT per day per member to calculate VMT per day by service type.
8. Multiply daily VMT in each car share service type by the percent vehicle efficiency improvements (based on average car share vs non-car share vehicle fuel consumption rate) for each service type and by average vehicle emission rates to calculate GHG reductions due to car share members driving more fuel-efficient vehicles.
9. Sum GHG emission reductions due to car share members driving less (Step 6) and GHG reductions due to car share members driving more fuel-efficient vehicles (Step 8) to calculate total GHG reductions due to car sharing.

Results

The table below summarizes the CO_2 reductions due to car share.

Table 47. CO_2 emissions reductions due to car share

ALTERNATIVE	DAILY REDUCTION (SHORT TONS)		PER CAPITA REDUCTION FROM YEAR 2005 EMISSIONS (PERCENT)	
	Year 2035	Year 2050	Year 2035	Year 2050
Plan	-1,928	-2,173	-2.43%	-2.42%
EIR Alternative 1	-1,928	-2,171	-2.43%	-2.42%
EIR Alternative 2	-1,926	-2,171	-2.43%	-2.42%

Targeted Transportation Alternatives

Targeted transportation alternatives programs employ a variety of strategies, including individual travel consultation, organized events, and distribution of outreach and informational materials to encourage people to shift from driving alone to carpooling, transit, biking, or walking for any of their trips. These programs are “targeted” because they tailor activities and materials to focus on the travel needs and transportation options that are available in specific job centers or residential neighborhoods. Several MPOs and large cities in the U.S. administer these programs, partnering with local governments, transit agencies, employers, and transportation management associations to customize projects to different communities. In several cities, these types of programs have been operating for more than 10 years with documented positive results, including Portland (Ore.) Metro’s Regional Travel Options program, City of Portland’s SmartTrips program, and King County (Wash.)’s InMotion program.

Several public agencies in the Bay Area have successfully implemented similar programs. Two of the Climate Initiative Innovative Grant pilot projects funded by MTC from 2011-14, GoBerkeley and Connect, Redwood City!, included targeted transportation alternatives components. The former involved working with property managers to market travel options and provide free bus passes to residents of multifamily transit-oriented developments, while the latter included focused outreach to employers with billboard and print advertising to promote alternatives to driving alone.

MTC's Targeted Transportation Alternatives Program includes both residential and employer activities. The employer portion of the program will have a particular focus on supporting smaller employers to complement a separate strategy establishing commute trip reduction targets for larger employers (reflected in the travel model). The program is expected to reduce drive alone trips and associated VMT by encouraging travelers to shift to using active and shared modes for their commute and non-commute trips. By reducing single occupancy vehicle trips, the program will reduce GHG emissions.

The Targeted Transportation Alternatives strategy was included in Plan Bay Area 2040. MTC is currently developing a pilot project of this approach, which will inform implementation of a broader program.

GHG Reduction Quantification Approach

Off-model analysis is necessary to capture GHG reductions from targeted transportation alternatives programs. The mode choice models in Travel Model 1.5 were calibrated using the 2012-2013 California Household Travel Survey, so they do not capture the impacts of new strategies that change travel behavior such as this one. It is possible that these strategies will be captured by a future model once they have been implemented to the extent that they influence people's behavior and can be captured by the travel surveys, and once the model framework has been altered to include inputs that represent the presence of behavior change strategies.

Since Plan Bay Area 2040, the approach has been updated with a new cost per participant assumption based on a review of more recent evaluations from a broader set of similar programs across the country; the cost per household was increased significantly from $3.11 to $18.81 per household. This results in a more conservative estimate of program benefits per dollar of investment than identified in the last plan.

Inputs and Assumptions

To estimate the impacts of this program on traveler behavior, the analysis relies on evaluation data collected for similar programs implemented in other regions. For residential-focused programs, program evaluation information was obtained for the City of Portland's SmartTrips program, King County's InMotion Program, SANDAG's Travel Encinitas pilot program, and the Community Transit (Snohomish County, Wash.) Curb the Congestion program. For employer-focused programs, evaluation information was obtained for Portland Metro's Regional Travel Options program. Some of these programs have conducted multiple rounds of evaluation, with each round covering multiple projects. Information was collected on the cost per year of marketing to an individual household/employee, the percentage of residents/employees receiving program information who change behavior (penetration rate), and the reduction in SOV mode share for those residents/employees from evaluations of these programs. These were then applied to the daily number and distance of trips for all trips (for households) and for commute trips (for employees) to estimate VMT impacts.

Evaluations of targeted transportation alternatives programs typically focus on impacts during the year after programs are implemented; however, long-term evaluations that provide information on how long behavior change persists due to marketing and outreach programs are not currently available. To account for this uncertainty, the methodology uses a conservative assumption that behavior change lasts for five years before participants revert to their previous travel patterns.

Table 48. Targeted Transportation Alternatives calculation assumptions

PARAMETER	HOUSEHOLDS	EMPLOYEES	SOURCE
Average cost per year of marketing to a household/ employee	$18.81	$4.34	Portland, OR and King and Snohomish Counties, WA program evaluations
Average penetration rate	19%	33%	Portland, OR and King and Snohomish Counties, WA program evaluations; Assumption based on discussion with Portland Metro Regional Travel Options program staff
Average reduction in SOV mode share among participants	12%	9%	Portland, OR and King and Snohomish Counties, WA program evaluations; Portland Metro, Regional Travel Options 2012 Program Evaluation
Average daily one-way driving trips affected	5.47	2	MTC, Characteristics of Rail and Ferry Station Area Residents in the SF Bay Area
Average one-way trip length (miles)	6.2 (2035); 5.8 (2050)	10.0 (2035); 9.8 (2050)	Travel Model, Plan scenario
Number of years for which behavior change persists	5	5	Assumption based on discussion with SANDAG Community Based Travel Planning program consultant

MTC's investment in this strategy is the primary input in the GHG reduction estimates. MTC anticipates investing $5 million in this strategy per year, with $3 million going to residential programs and $2 million going to employee programs. MTC is working with consultants to develop an approach to implementation beginning in 2021. Implementation of the program is expected to continue through the lifetime of the plan years due to the assumption that behavior change from program interventions is temporary. The program is applied to all households and jobs in the region for each modeled year. Based on the annual investment assumption and cost per household or employee, the program is expected to reach approximately 160,000 households and 460,000 employees.[70]

70 2018 National Establishment Time Series (NETS) data indicates that there are approximately 2.5 million people in the Bay Area who work for establishments with less than 50 employees.

Calculation Methodology

The methodology for calculating the GHG reductions from the Targeted Transportation Alternatives strategy is as follows:

1. Allocate the investment between household and employee programs.
2. Divide the respective household/employee investments by the average cost per year of marketing to a household/employee and multiply by the penetration rate to calculate the total number of participants.
3. Multiply the total number of participants by the average reduction in SOV mode share among participants and the average daily one-way driving trips affected and the average number of years that behavior change will persist to calculate the total daily number of vehicle trips reduced due to total program funding.
4. Sum the total daily vehicle trip reductions for employees and households to calculate the total daily vehicle reductions.
5. Multiply daily vehicle trips reduced by the average one-way trip length to calculate the total daily VMT reductions.
6. Sum the product of trip-end emission rates and daily vehicle trip reductions and the product of exhaust emission rates and daily VMT reductions to calculate total GHG emission reductions.

Results

The table below summarizes the CO_2 reductions due to Targeted Transportation Alternatives.

Table 49. CO_2 emissions reductions due to Targeted Transportation Alternatives

ALTERNATIVE	DAILY REDUCTION (SHORT TONS)		PER CAPITA REDUCTION FROM YEAR 2005 EMISSIONS (PERCENT)	
	Year 2035	Year 2050	Year 2035	Year 2050
Plan	-883	-861	-1.11%	-0.96%
EIR Alternative 1	-877	-847	-1.11%	-0.94%
EIR Alternative 2	-872	-862	-1.10%	-0.96%

Vanpool Incentives

MTC has coordinated a vanpool program since 1981 to encourage alternative commutes and reduce congestion and emissions. To date, MTC's 511 vanpool program recruitment has consisted of online passenger and driver matching, employer outreach, up to $500 for startup fees, empty seat subsidies to encourage continued participation when a passenger is lost, free bridge tolls, discounted parking permits, and various other incentives. With these basic incentives there is an operational vanpool fleet in the Bay Area of more than 500 vans.

As defined by the 511 program, a vanpool is a group of seven to 15 people commuting together and being driven by an unpaid driver. There are a handful of options for drivers to procure a vehicle: the first is simply a vehicle that is owned by the driver, the second is a vehicle provided by an employer, and the third option is renting a vehicle from a third-party provider. MTC modified its vanpool program to be similar to programs in San Diego, Los Angeles, Denver, Arizona and elsewhere. San Diego's program began in 2001 and saw 5% to 10% growth in the vanpool fleet every year through FY 2013. Los Angeles Metro began its program in 2007 and the vanpool fleet has grown about 14% per year.

The vanpool program was included in previous regional plans and MTC will continue supporting vanpooling across the region in Plan Bay Area 2050. Through a partnership with Enterprise Rent-A-Car, groups may be eligible for a $350 monthly subsidy for vanpool vehicles rented through the Commute with Enterprise program.[71] Currently vanpool rentals cost approximately $1,300 to rent and operate per month.[72] The $350 per month subsidy would reduce these costs by 27%. MTC assumes this incentive will significantly increase the vanpool fleet. Combined with growth in Bay Area population, employment, and highway congestion, the size of the Bay Area vanpool fleet is expected to reach 1,030 vans by 2035, after which the number of vanpools is assumed to stabilize. A sustained fleet of 1,030 vans is slightly more than the 1996 peak of 900 vans. Moreover, there is significant potential to expand vanpool operations in the Bay Area. For comparison, the Puget Sound region operates more than 1,700 vanpool vans compared to the Bay Area's 515 vans, with a population that is 54% of the Bay Area's.[73] In addition to financial subsidies, MTC works with vanpool groups, both in Commute with Enterprise and other vanpools, to provide technical assistance such as ride matching tools, identification of incentives (e.g., parking and bridge toll discounts), form completion guidance, and social media promotion resources to help form and fill vanpools.

GHG Reduction Quantification Approach

Travel and emissions impacts are calculated based on the number of vanpool program vans, average vanpool occupancy, and the relationship between vehicle trip reductions and VMT reductions. Vanpool incentives reduce GHG emissions by encouraging groups of people to share a ride for their commute, which reduces travel by single occupancy vehicles and associated VMT. The vanpool incentive program is not captured by MTC's travel model and thus, the emission reductions resulting from this strategy are not otherwise captured. Travel Model 1.5's mode choice models are calibrated using the 2012-2013 California Household Travel Survey (CHTS).

The overall quantification approach remains unchanged from Plan Bay Area 2040 but uses updated driving mode shares from Plan Bay Area 2050. The impacts of the vanpool incentive program are calculated based on the difference between the number of vanpools in existence since 2005 (515 vans) and the number expected in the future with an expanded program.

Inputs and Assumptions

In this analysis, the base year vanpool fleet of 515 vans is assumed to double by 2035 and remain at this level through 2050. Average vanpool occupancy, which is used to calculate the total daily vehicle trip reductions, is determined with data gathered from MTC's 511 program and is assumed to stay consistent over time.

The emission reduction analysis assumes that vanpools have an average of 10.8 passengers and roundtrip distance of 110 miles[74], both of which are expected to remain constant over time. To account for the emissions from the vanpool van itself, the calculations account for only 9.8 passengers in the van. Reducing the vanpool size is a simplified approach to account for the emissions from the shared van.

The population that shifts to vanpools is expected to be consistent with the commute mode share of the general population. Emissions reduced from a commuter switching from a single occupancy vehicle (SOV) are assumed to be 100%. Emissions reduced from a commuter switching from a two-person carpool are assumed to be 50%. Emissions reduced from a commuter switching from a 3+ person carpool are assumed to be 33%. Shifts from other modes (walking, biking, or transit modes) are not assumed to reduce emissions.

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71 MTC Bay Area Vanpool Program, Commute with Enterprise, https://511.org/vanpool/enterprise.

72 Based on MTC staff conversations with vanpool users.

73 Ennis, Michael (2010). Vanpools in the Puget Sound Region: The case for expanding vanpool programs to move the most people for the least cost. Washington Policy Center for Transportation.

74 MTC Transit Finance Working Group memo, February 2015.

Since the baseline year for the SB 375 emissions reduction target is 2005, the current vanpool fleet of 515 vans is not included in the analysis; only growth above and beyond 515 vans is included in the calculations.

Table 50. Vanpool calculation inputs and assumptions

PARAMETER	VALUE	SOURCE
Baseline number of vans, 2005	515	MTC data, 2005-2011
Average vanpool occupancy	10.8	MTC data, 2005-2011
Vanpool program vans, 2035-2050	1,030	Assume doubling of the baseline fleet by 2035 and sustained stabilized fleet after 2035

The vanpool incentive is expected to be self-funding. Reporting ridership mileage to the National Transit Database (NTD) returns Federal Transit Administration (FTA) funding to the region for transit. Several other cities and regional agencies, including San Diego, Los Angeles, Denver, and Arizona, have found that NTD reporting of vanpool data returns more money to a jurisdiction than the amount spent to offset vanpool costs. For example, the Northern Virginia Transportation Commission found that failure to report vanpool data in the Washington, D.C. metropolitan area resulted in a $6 million to $8 million loss per year, and that each $1 invested would have returned more than $2 in transit funds.[75] Los Angeles spends $7 million annually to offset vanpool costs and brings back $20 million in additional transit funding.[76] While the amount returned varies depending on the number of passenger miles traveled, vanpools that log more miles and carry more passengers have higher returns. MTC estimates that for every $1 spent on vanpools, it could expect a return of about $1.40 in transit funds.

Calculation Methodology

To calculate the GHG emission reductions resulting from the vanpool incentive program, the analysis steps were as follows:

1. Multiply the projected increase in vanpools by the number of passengers (minus the driver) to obtain increased number of vanpool participants.

Number of vanpool participants	$= (V_{2035} - V_{2005}) * (Pass_{avg} - 1)$

Where:

V = number of vanpools

$Pass_{avg}$ = average number of passengers per van (10.8)

2. Estimate the number of vehicle round trips reduced by vanpools, accounting for the previous mode selection of the vanpool participants, by multiplying the number of vanpool participants by each of the vehicle mode shares and an adjustment factor that accounts for the number of passengers and summed the results.

75 Northern Virginia Transportation Commission; FTA Section 5307 Earnings Potential from Vanpools in DC Metropolitan Region; Revised: August 7, 2009.

76 MTC October 2014 interview with LA Metro program manager, Jamie Carrington.

Number of vehicle round trips reduced by vanpools	$= (P * MS_{SOV}) + (P * MS_{HOV2} * 0.5) + (P * MS_{HOV3} * 0.33)$

Where:

P = vanpool participants

MS_{SOV} = drive alone mode share

MS_{HOV2} = 2-person carpool mode share

MS_{HOV3} = 3+ person carpool mode share

3. Multiply number of vehicle round trips reduced by the round trip vanpool mileage to obtain daily VMT reduced.

4. Sum the product of trip-end emission rates and daily vehicle trip reductions and the product of exhaust emission rates and daily VMT reductions to calculate total GHG emission reductions.

Results

The table below summarizes the CO_2 reductions due to vanpool programs.

Table 51. CO_2 emissions reductions due to vanpool strategy

ALTERNATIVE	DAILY REDUCTION (SHORT TONS)		PER CAPITA REDUCTION FROM YEAR 2005 EMISSIONS (PERCENT)	
	Year 2035	Year 2050	Year 2035	Year 2050
Plan	-131	-122	-0.17%	-0.14%
EIR Alternative 1	-131	-121	-0.16%	-0.13%
EIR Alternative 2	-129	-113	-0.16%	-0.13%

Regional Electric Vehicle Charger Program

Electric vehicles (EVs) have the potential to significantly reduce GHG emissions from motor vehicles. Today, the Bay Area is the leading U.S. market for EV sales, including both plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs). PHEVs have a hybridized powertrain that is fueled by chemical energy from a battery or by gasoline/diesel. BEVs are powered exclusively by the chemical energy from a battery. The focus of this strategy is on expanding the charging opportunities for the population of PHEVs in the Bay Area by establishing a regional public network of electric vehicle charging stations.

The costs of installing charging stations can be high, and there are other barriers (e.g., on-site electrical capacity) that may also limit the potential for deploying charging at workplaces. This program will be designed to help overcome some of those barriers by providing financial assistance to interested employers, retailers, parking management companies, and others that qualify. A regional network of charging infrastructure will provide drivers an opportunity to plug in while at work, which is where most vehicles spend most of their time parked when not at home. This will mean that PHEVs are able to travel more miles using electricity and fewer miles using gasoline, reducing GHG emissions.

This strategy was included in Plan Bay Area 2040 and continues in Plan Bay Area 2050. In 2017, MTC transferred a total of $10 million to the Bay Area Air Quality Management District (BAAQMD) to advance EV strategies. BAAQMD currently administers the Charge! Program, providing grant funding for the purchase and installation of publicly accessible chargers for light-duty EVs. MTC continues to work with BAAQMD to deliver a coordinated approach to implementing charging infrastructure throughout the region.

GHG Reduction Quantification Approach

This strategy invests in charging infrastructure to expand the network of chargers available to Bay Area drivers. As a result, PHEV drivers will be able to drive a larger share of miles in electric mode, as opposed to gasoline-powered mode, reducing GHG emissions. The impacts of this strategy are not otherwise captured in MTC's emissions calculations, which rely on default EMFAC assumptions for the fraction of PHEV miles in electric vs. gasoline mode.

Inputs and Assumptions

Plan Bay Area 2040 analysis was updated to account for improved fuel economy estimates, updated vehicle populations, and new vehicle sales in the Bay Area based on data included in the EMFAC2014 (v1.0.7) Emissions Inventory and the ZEV Compliance Mid-Range Scenario of the Advanced Clean Cars Mid-term Review. The analysis also updated the number of chargers to be funded by MTC and deployed to support the region's PHEV population.

In the baseline, it was assumed that 46% to 60% of miles traveled by PHEVs would be in charge-depleting mode (i.e., electric miles instead of gasoline-powered miles). This assumption comes from EMFAC2017 Technical Documentation, which indicates that:

To estimate the fraction of PHEVs that operates like pure ZEVs, EMFAC uses utility factors, which are defined as the fraction of VMT the PHEV obtains from the electrical grid. EMFAC2014 was assuming a constant utility factor of 0.4 for all model years of PHEVs, while in EMFAC2017 this fraction is more dynamic and varies by model years from 0.46 for Model Year (MY) 2018 to 0.6 for MY2025+.[77]

The electric VMT (eVMT) percentage is assumed to increase to 80% due to the Regional Charger Program. Based on a review of EV user surveys and analytics included in the Advanced Clean Cars Mid-Term Report[78], data suggest that PHEV owners can reach 80% eVMT with access to adequate supportive charging infrastructure. This analysis assumes that if the entire region has sufficient workplace and opportunity (public) charging infrastructure, then all PHEVs in the region could operate at this assumed maximum eVMT percentage.

The analysis methodology assumes:

- Each charger deployed through the Regional Charger Network serves multiple vehicles each day
- The chargers deployed are Level 2 chargers
- Each charger consists of two plugs

The National Renewable Energy Laboratory's EVI Pro Lite tool was used to determine the number of chargers required to support the forecasted PHEV population. While the ratios vary by PHEV penetration, it is approximately one charger plug for every four vehicles over the program period. For the financial analysis, the strategy assumes a $3,000 subsidy per charger is provided.[79] The table below summarizes the number of expected PHEVs, plugs, and chargers by analysis year.

77 California Air Resources Board, EMFAC2017 Volume III – Technical Documentation V1.0.2, July 20, 2018. Available online at https://ww3.arb.ca.gov/msei/downloads/emfac2017-volume-iii-technical-documentation.pdf.

78 California Air Resources Board, Advanced Clean Cars Mid-Term Report, Appendix G: Plug-in Electric Vehicle In-Use and Charging Data Analysis, January 18, 2017. Available online at https://ww2.arb.ca.gov/resources/documents/2017-midterm-review-report.

79 Note that the methodology uses the projected PHEV population from EMFAC and EVI-Pro to estimate the total number of chargers required across the region to meet that forecasted PHEV population; the incentive amount is used to calculate the total investment required to meet this demand.

Table 52. Expected PHEVs, plugs and chargers by analysis year

PARAMETER	2035	2050	SOURCE
PHEV population	363,012	458,818	EMFAC2014
Plug/PHEV ratio	0.2352	0.2352	EVI-Pro
Charging plugs needed	85,384	107,918	Calculation
Chargers needed	42,692	53,959	Calculation
Incentive amount ($/charger)	$3,000	$3,000	Investment assumption

In addition to increasing the percentage of electric miles driven in PHEVs, the increased availability of chargers could mitigate consumers' "range anxiety" concerns and increase the adoption and use of EVs and further reduce GHG emissions, but this potential effect is not included in this approach, as a conservative assumption. Further, this approach does not include any additional PHEVs incentivized through the Vehicle Buyback & EV Incentive strategy or any increased eVMT share for those PHEVs; the baseline eVMT share is applied to PHEVs realized through that strategy rather than the higher eVMT share assumed in the regional charger network scenario, also as a conservative assumption.

Calculation of emissions impacts relies on the parameters shown in the table below.

Table 53. Regional electric vehicle strategy calculation inputs and assumptions

PARAMETER	VALUE	SOURCE
Fuel efficiency of PHEV gasoline engine	40 mpg	24.9 mpg for gasoline LDV, based on EPA Automotive Trends Report, 2020; 62% improvement for PHEV engine based on comparison of similar gasoline and hybrid models
Baseline eVMT share for PHEVs – pre MY2025	46%	EMFAC2017 Volume III Technical Documentation
Baseline eVMT share for PHEVs – MY2025+	60%	EMFAC2017 Volume III Technical Documentation
Strategy eVMT share for PHEVs	80%	CARB, Advanced Clean Cars Mid-Term Report, 2017
Energy density of gasoline	115.83 MJ/gallon	CA GREET 3.0
Carbon intensity of gasoline (tailpipe)	72.89 gCO_2/MJ	CA GREET 3.0

Calculation Methodology

To determine the GHG emission reductions from the Regional Charger Program, the analysis method employs the following steps:

1. Use EMFAC to obtain the forecast population of EVs in the Bay Area through 2050, by calendar year and model year.
2. Process EV population data to estimate the population of PHEVs by calendar year and model year.
3. Calculate baseline PHEV eVMT by calendar year, using assumptions in EMFAC2017 that eVMT percentage is 46% for MY2018-2024 and 60% for MY2025+.
4. Calculate baseline PHEV emissions, multiplying baseline PHEV VMT for each calendar year by average fuel efficiency, energy density, and carbon intensity.
5. Apply strategy eVMT percentage to calculate difference in eVMT between baseline and strategy scenario.
6. Calculate PHEV emissions in strategy scenario.
7. Calculate GHG emissions reduction as the difference between the baseline and strategy scenario PHEV emissions.

Results

The table below summarizes the CO_2 reductions due to the Regional Electric Vehicle Charger Program.

Table 54. CO_2 emissions reductions due to Electric Vehicle Charger Program

ALTERNATIVE	DAILY REDUCTION (SHORT TONS)		PER CAPITA REDUCTION FROM YEAR 2005 EMISSIONS (PERCENT)	
	Year 2035	Year 2050	Year 2035	Year 2050
Plan	-741	-792	-0.93%	-0.88%
EIR Alternative 1	-741	-792	-0.93%	-0.88%
EIR Alternative 2	-741	-792	-0.93%	-0.88%

Emission reductions are consistent across all EIR Alternatives since the analysis does not rely on inputs from the travel model.

Vehicle Buyback and EV Incentive

Despite a rapid increase in commercially available electric vehicle (EV) models, EV sales are still relatively small, representing about 8 percent of total new light-duty vehicle sales in California. While falling battery prices are expected to make EVs more attractive to consumers, there are also barriers related to EV costs and benefits. The price of new EVs is still beyond the reach of many potential new vehicle buyers, particularly lower-income consumers. To begin addressing this challenge, California's Clean Vehicle Rebate Program (CVRP) was changed in 2016 to adjust incentive amounts based on household income. HOV lane access for some EVs has been eliminated, reducing the non-financial incentives to own an EV. And without additional Congressional action, federal EV tax credits will phase out in their current format because the full tax credit applies only to the first 200,000 EVs sold per automaker; once the 200,000-unit limit is reached, the tax credit value decreases on a quarterly basis until it is phased out completely approximately one year after the automaker surpasses the threshold. Tesla was the first automaker to surpass the sales threshold in July 2018 and General Motors followed suit in December 2018. The early phase out and elimination of these tax credits could potentially have negative sales implications for the Tesla Model 3 and Chevy Bolt – two of the most popular EVs sold in California. Other EV manufacturers are expected to surpass the threshold in the coming years.

This program will provide an incentive to purchase an EV when trading in older, higher-emission vehicles. This is intended to extend the market for EVs into a broader range of income classes. Research indicates that the early adopters of EVs have been higher income individuals who own their homes, and in many cases, own or have owned a hybrid vehicle (e.g., a Toyota Prius). The higher purchase price of EVs makes it difficult for middle- and low-income consumers to purchase them. Older and wealthier individuals tend to buy more new vehicles than other cross-sections of the population. This demographic also tends to buy newer cars more frequently. Furthermore, research from IHS Markit has shown that owners of both new and used vehicles are holding on to their vehicles longer, the scrappage rate has flattened, and the average age of vehicles has increased; the researchers forecast that the population of oldest vehicles (16 or more years) will grow the fastest, increasing by 30% by 2021.[80] This will impact the turnover of the fleet significantly and may slow the purchase of new vehicles, including electric vehicles.

In this program, qualifying consumers can receive a subsidy to purchase a plug-in hybrid electric vehicle (PHEV) or battery electric vehicle (BEV) for scrapping a vehicle that is 15 or more years old. The incentive amount will vary with the vehicle type being purchased (e.g., PHEV or BEV). Additionally, to provide more equitable access to clean transportation options, incentive amounts will vary by household income level, with incentives phased out entirely for higher income buyers.

This strategy was included in Plan Bay Area 2040. In 2017, MTC transferred a total of $10 million to the Bay Area Air Quality Management District (BAAQMD) to accelerate EV adoption. MTC continues to coordinate with BAAQMD, the lead agency for electric vehicle programs in the region, to advance this strategy. In Plan Bay Area 2050, a significantly larger investment is envisioned with incentive amounts adjusted based on buyer income.

GHG Reduction Quantification Approach

The vehicle buyback program seeks to accelerate fleet turnover while also incentivizing the purchase of EVs. The combination vehicle buyback and incentive program is intended to induce demand in middle- and lower-income brackets that might otherwise delay car purchasing or purchase a new or used conventional vehicle (i.e., non-EV). The program will result in a higher fraction of EVs owned and operated in the Bay Area than assumed in default EMFAC assumptions.

Inputs and Assumptions

Plan Bay Area 2040 analysis was revised to account for improved fuel economy estimates, increased incentive amounts and program participation, impacts of the State's incentive program, and the mix of PHEVs vs. BEVs incentivized. The program is assumed to be implemented through 2035's incentive program, is assumed to be equal across the program years. The age of the vehicles being replaced is assumed to be 15 years or older.

80 Vehicles Getting Older: Average Age of Light Cars and Trucks in U.S. Rises Again in 2016 to 11.6 Year, IHS Markit Says." Press release from IHS Markit, November 2016.

The program incentives are assumed to range from $1,800 to $13,600, with average incentive levels of $3,600 per PHEV and $8,100 per BEV; the program incentive will vary based on income and EV type.[81] The State's primary EV incentive program, the Clean Vehicle Rebate Project (CVRP), is assumed to provide additional purchase incentive amounts on top of the plan strategy in the amount of $3,500 per PHEV and $4,500 per BEV for households with incomes below $50,000, $1,000 per PHEV and $2,000 per BEV for households earning up to $170,000, and no rebates for the highest income households.[82] The program assumes a $5.1 billion investment through 2035, incentivizing buyback and purchase of 630,000 EVs. It is assumed that 30 percent of incentives are used for PHEVs and 70 percent for BEVs, based on the share of EV types receiving California Vehicle Rebate Project incentives over the period 2017-2019.

Calculation of emissions impacts relies on the parameters shown in the table below.

Table 55. Vehicle Buyback and EV incentive calculation inputs and assumptions

PARAMETER	VALUE	SOURCE
Fuel efficiency of PHEV gasoline engine	40 mpg	24.9 mpg for gasoline LDV, based on EPA Automotive Trends Report, 2020; 62% improvement for PHEV engine based on comparison of similar gasoline and hybrid models
Share of incentivized EV types	70% BEV, 30% PHEV	CVRP rebate data, average 2017-19
eVMT share for PHEVs – pre MY2025	46%	EMFAC2017
eVMT share for PHEVs – MY2025+	60%	EMFAC2017
Energy density of gasoline	115.83 MJ/gallon	CA GREET 3.0
Carbon intensity of gasoline (tailpipe)	72.89 gCO_2/MJ	CA GREET 3.0

81 A consultant review of EV models and equivalent non-EV models (e.g., Volkswagen Golf vs eGolf) found the average difference in cost to be $13,600 The program is assumed to cover the full difference in cost for households in the lowest income quartile. Purchase subsidies for the second and third quartile households are scaled relative to income quartile thresholds; no subsidies are assumed for the highest quartile earners. It is assumed that the participation level across the three qualifying income groups will be equal.

82 California Clean Vehicle Rebate Project incentive amounts based on current (2021) program structure offering $1,000 per PHEV and $2,000 per BEV for consumers earning up to $150,000 (single filers) and an additional $2,500 for consumers earning less than $51,520 (household size 1). Rebate amounts and income eligibility information collected from CVRP website (accessed August 11, 2021): https://cleanvehiclerebate.org/eng.

Calculation Methodology

To determine the GHG emission reductions from the Vehicle Buyback & EV Incentive Program, the analysis method employs the following steps:

1. Calculate the number of new PHEVs and BEVs incentivized through strategy for each program year.
2. Calculate the cumulative number of incentivized PHEVs and BEVs operating in each calendar year, accounting for average vehicle turnover by vehicle age.[83]
3. Use EMFAC forecasts of vehicle populations, fuel consumption, and VMT for gasoline light-duty automobiles (LDA – Gas) in the Bay Area to calculate the average gasoline consumption per replaced vehicle (for vehicles 15 years old), by calendar year.
4. Calculate the GHG emissions impact of the program, by calendar year, as the difference between emissions from the replaced vehicles and the emissions from the incentivized EVs, using average carbon intensity values for electricity and gasoline, average energy density for electricity and gasoline, and average energy efficiency for gasoline and electric motors.
5. Calculate MPO regional incentive share of combined MPO and State incentive amount for PHEVs and BEVs.
6. Apply MPO incentive share to GHG emissions impact for each program calendar year to calculate MPO share of GHG emission reductions.

Results

The table below summarizes the CO_2 reductions due to the Vehicle Buyback and EV Incentive Program.

Table 56. CO_2 emissions reductions due to Vehicle Buyback and EV Incentive Program

ALTERNATIVE	DAILY REDUCTION (SHORT TONS)		PER CAPITA REDUCTION FROM YEAR 2005 EMISSIONS (PERCENT)	
	Year 2035	Year 2050	Year 2035	Year 2050
Plan	-3,271	-503	-4.12%	-0.56%
EIR Alternative 1	-3,271	-503	-4.12%	-0.56%
EIR Alternative 2	-3,271	-503	-4.12%	-0.56%

Emission reductions are consistent across all EIR Alternatives since the analysis does not rely on inputs from the travel model.

83 A share of these new EVs are assumed to be removed from operation (e.g., as a result of collisions) each year, with higher turnover rates for older model years.

Performance and Equity Analysis

The purpose of this document is to describe the response of travelers to the strategies implemented in the Plan as compared to the No Project and EIR Alternatives. Information from the travel model was also used to help assess the performance of each alternative using the adopted Plan Bay Area 2050 Guiding Principles as a framework.

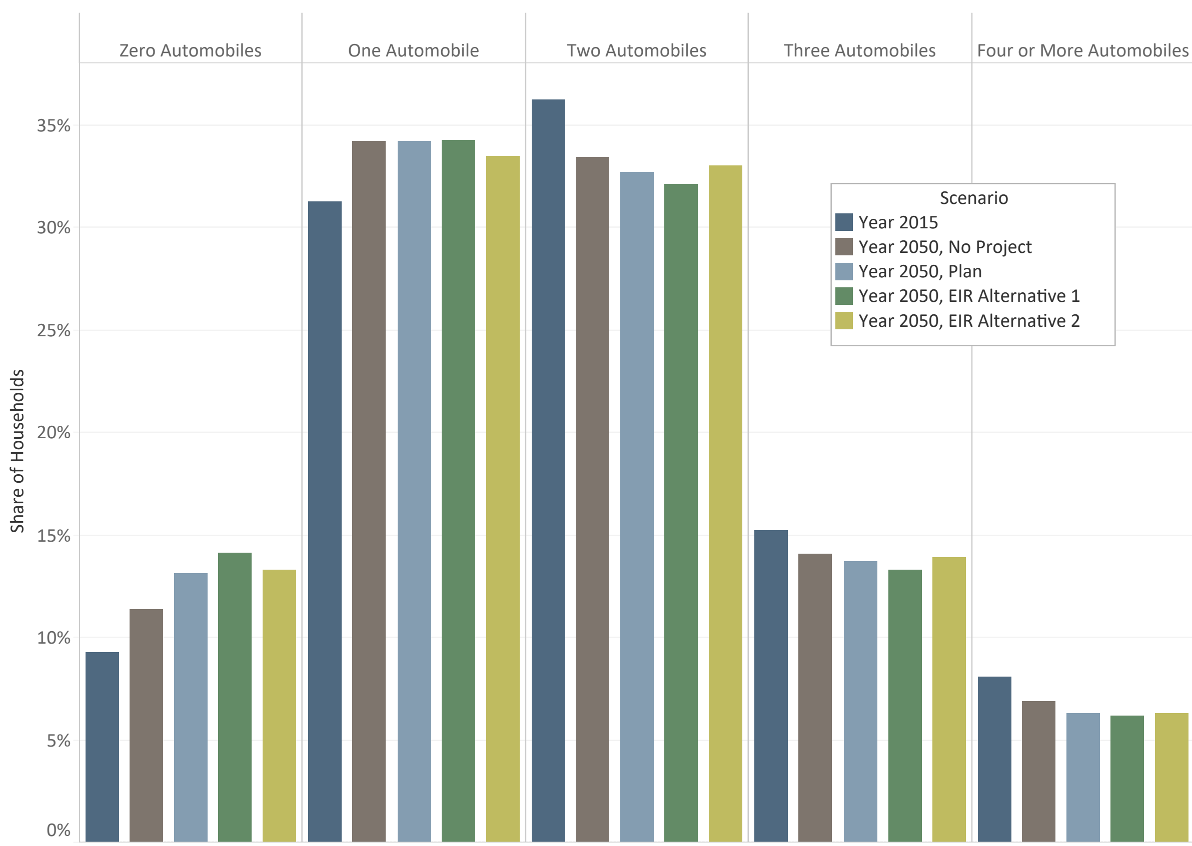
Greenhouse Gas Emissions

The above section on Off-Model Calculations describes how the Plan strategies which couldn't be represented in the travel model were estimated to contribute to the reduction of greenhouse gas emissions from transportation. More information about how the Plan achieves the Sustainable Communities and Climate Protection Act of 2008 (SB 375) 2035 targets for per-capita greenhouse gas emission reductions compared to 2005 levels can be found in the Environmental Impact Report for Plan Bay Area 2050, in Chapter 3.6: Climate Change, Greenhouse Gases, and Energy. Information about how the Bay Area achieved the 2020 greenhouse gas emissions targets can be found in MTC's Technical Methodology for the Sustainable Communities Strategy.

Automobile Ownership

Figure 31 presents the automobile ownership rates across the four alternatives in the year 2050 simulations as well as year 2015. Recall that one of the key factors affecting auto ownership between 2015 and 2050 is the assumption of some autonomous vehicle fleet penetration, which reduces the need for higher auto ownership levels per household because households with autonomous vehicles can share more easily. Beyond that, the Plan strategies enable slightly higher rates of zero automobile households, as do the land use patterns and strategies retained in the EIR Alternatives.

Figure 31. Auto ownership results in 2050 across alternatives



Activity Location Decisions

Figure 32 and Figure 33 present the average trip distance by travel mode for all travel and for trips on work tours, respectively. The key finding here is that the EIR Alternative 1 brings activities slightly closer together, when compared to 2050 Alternatives.

Figure 32. Average trip distance in 2050 across alternatives

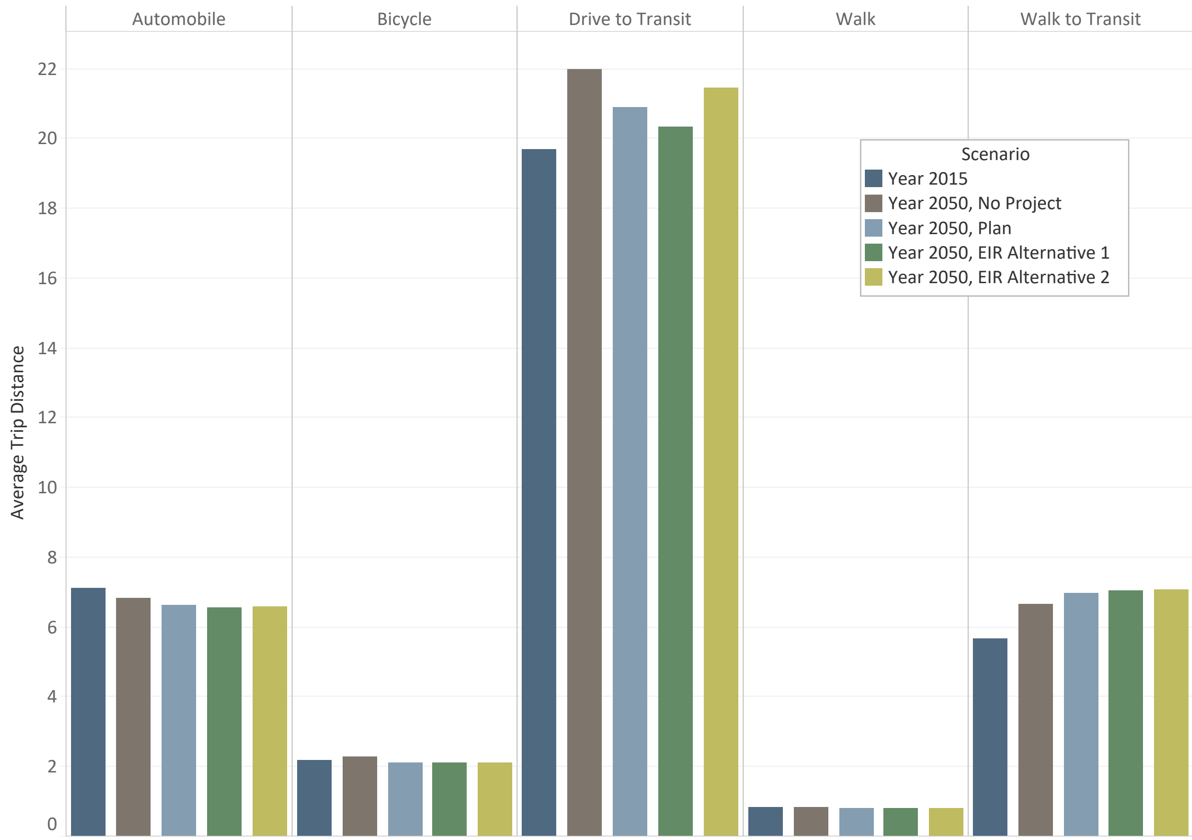
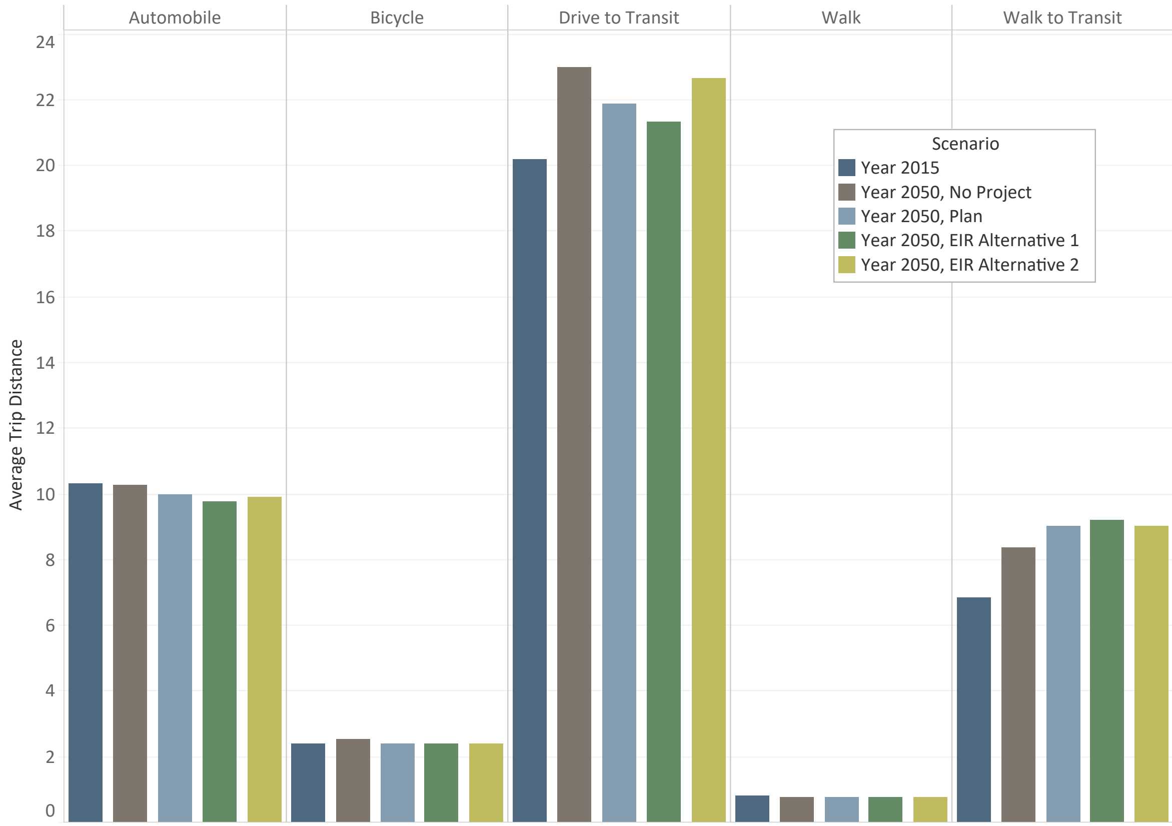


Figure 33. Average trip distance for travel on work tours in 2050 across alternatives



Travel Mode Choice Decisions

The means by which a traveler gets from point A to point B is referred to as the travel mode. Within MTC's representation of travel behavior, seven automobile-based modal options are considered, specifically:

1. traveling alone in a private automobile and opting not to pay to use a tolled lane ("Single Occupant, No Toll"), an option only available to those in households who own at least one automobile;
2. traveling alone in a private automobile and opting to pay to use a tolled lane ("Single Occupant, Paying Toll"), an option only available to those who both own a car and whose journey would benefit from using the tolled facility (e.g., this option is not available to those driving through a residential neighborhood to drop a child at school);
3. traveling with one passenger in a private automobile and opting not to pay to use a tolled lane ("Two Occupants, No Toll) (these travelers can use carpool lanes for which they are eligible), an option available to all households;
4. traveling with one passenger in a private automobile and opting to pay to use a tolled lane ("Two Occupants, Paying Toll"), an option available to all households provided they would benefit from using a tolled lane (if the tolled lane facility which benefits travelers allows two-occupant vehicles to travel for free, then these travelers are categorized as "Two Occupants, No Toll");
5. traveling with two or more passengers in a private automobile and opting not to pay to use a tolled lane ("Three or More Occupants, No Toll")
6. travelling with two or more passengers in a private automobile and opting to pay to use a tolld lane ("Three or More Occupants, Paying Toll"), an option available to all households provided they would benefit from using a tolled lane (if the tolled lane facility which benefits travelers allows three-occupant vehicles to travel for free, then these travelers are categorized as "Three Occupants, No Toll"); and
7. traveling using a taxi, transportation network company (TNC) vehicle -- either pooled with another party or as a single party; this option is available to all households.

The travel model explicitly considers numerous non-automobile options which are collapsed in these summaries into the following four options: transit, getting to and from by foot ("walk to transit"); transit, getting to or from in an automobile ("drive to transit"); walk; and bicycle.

Figure 34 and Figure 35 present the share of trips made by various travel modes. Figure 34 shows shares of travel in automobiles by occupancy category as well as by willingness to pay to use a tolled lane. The effect of Strategy T5 to Implement Means-Based Per-Mile Tolling on Congested Freeways with Transit Alternatives is clearly visible here as a large proportion of automobile trips become toll-paying trips. Overall, the shift towards the bike mode driven by Strategy T8: Build a Complete Streets Network is clearly visible in the three EIR Alternatives, as well as a slight shift towards transit.

Figure 34. Year 2050 automobile mode shares for all travel in 2050 across alternatives

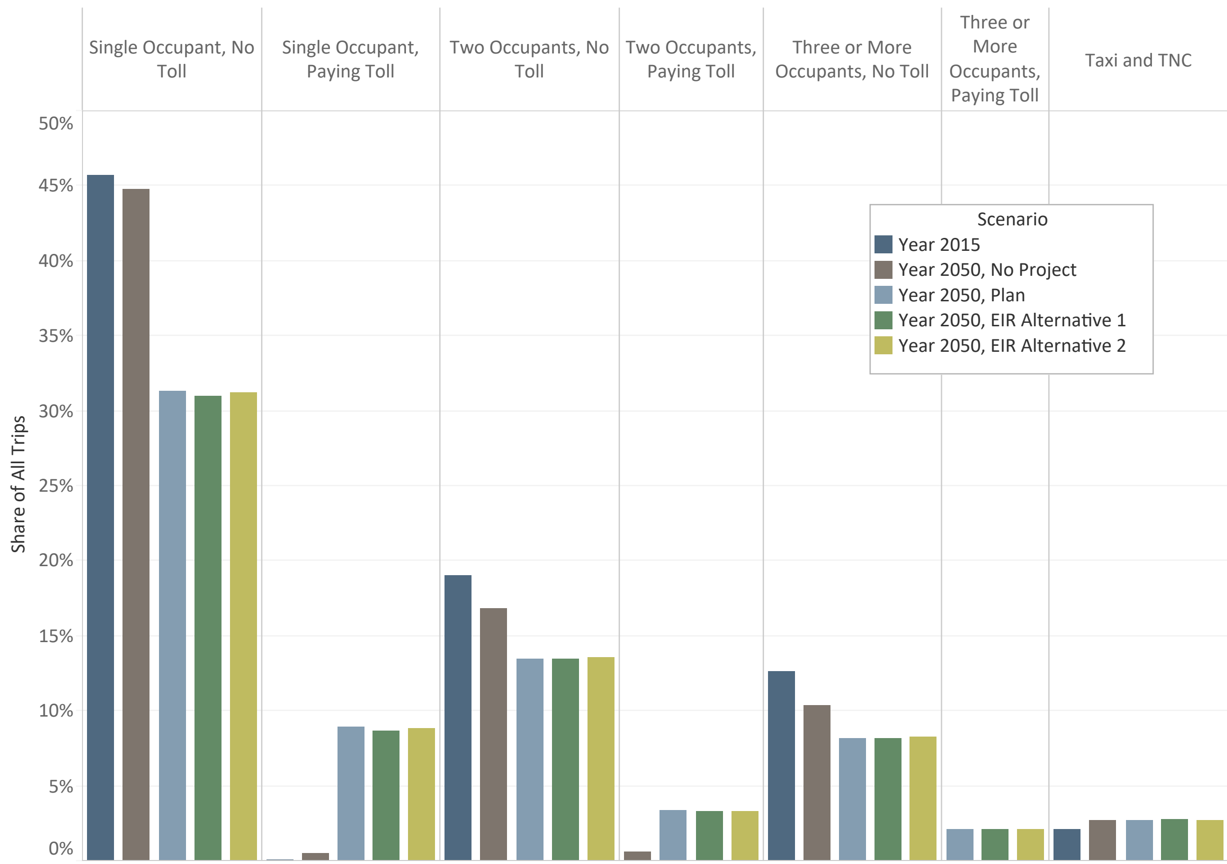
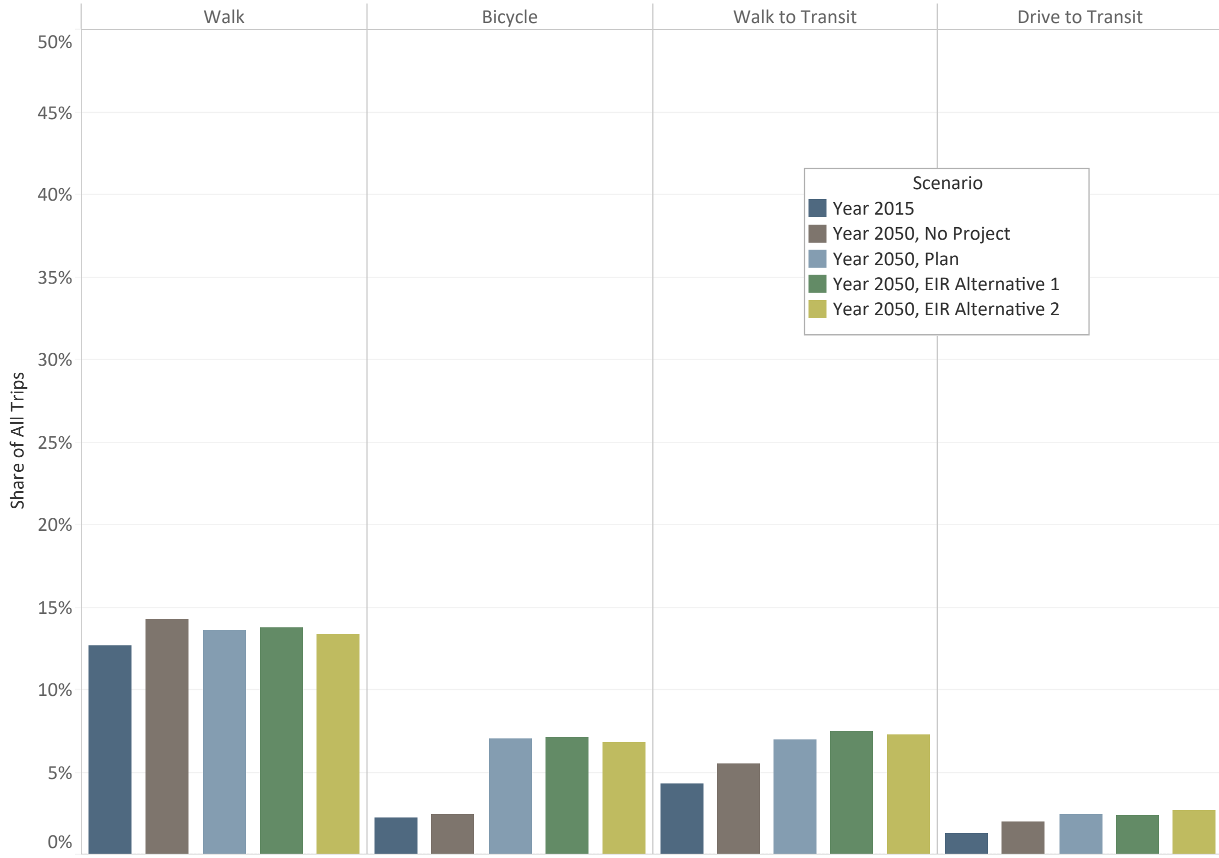


Figure 35. Non-automobile mode shares for all travel in 2050 across alternatives



Aggregate Transit Demand Estimates

Bay Area residents choosing to travel by transit are explicitly assigned to a specific transit route. As a means of organizing the modeling results, MTC groups transit lines into the following technology- specific categories:

1. **Local bus:** standard, fixed-route bus service, of the kind a traveler may take to and from a neighborhood grocery store or to work, as well as “bus rapid transit” service. Cable cars are included in this category.

2. **Express bus:** longer distance service typically provided in over-the-road coaches. Golden Gate Transit, for example, provides express bus service between Marin County and Downtown San Francisco.

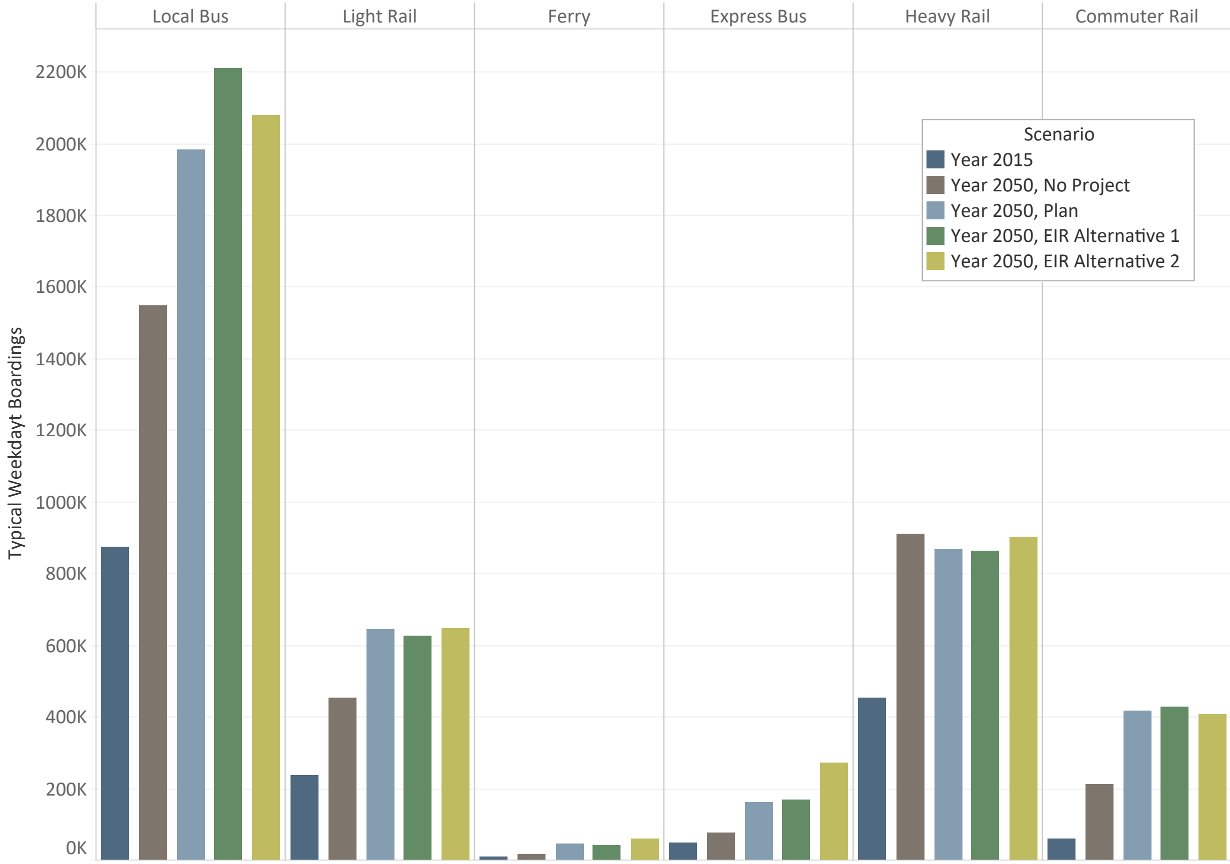
3. **Light rail:** represented in the Bay Area by San Francisco’s Muni Metro and streetcar services (F- Market and E-Caltrain), as well as Santa Clara Valley Transportation Authority’s light rail service.

4. **Heavy rail:** another name for the Bay Area Rapid Transit (BART) service.

5. **Commuter rail:** longer distance rail service typically operating in dedicated right-of-way, including Caltrain, Sonoma-Marin Area Rail Transit (SMART), Amtrak’s Capitol Corridor, and Altamont Commuter Express.

Figure 36 presents the estimates of transit boardings by these categories on the typical weekday simulated by the travel model. Ridership increases from about 1.7 million daily boardings in 2015 to 3.1 million daily boardings in 2050 No Project, and 4 million daily boardings in all project scenarios in 2050.

Figure 36. Typical weekday transit boardings by technology in 2050 across alternatives



Roadway Utilization and Congestion Estimates

Trips made by automobile are first aggregated into matrices identifying each trip's origin and destination, and then "assigned" to a representation of the Bay Area's roadway network. The assignment process iteratively determines the shortest path between each origin-destination pair, shifting some number of trips to each iteration's shortest path, until the network reaches a certain level of equilibrium – defined as a state in which travelers cannot change to a lower "cost" route (where cost includes monetary and non-monetary (time) expenditures). Several measures of interest are generated by the assignment process, including vehicle miles traveled, delay, and average travel speed.

Please note that MTC maintains two separate estimates of the quantity of vehicle miles traveled (VMT), as follows:

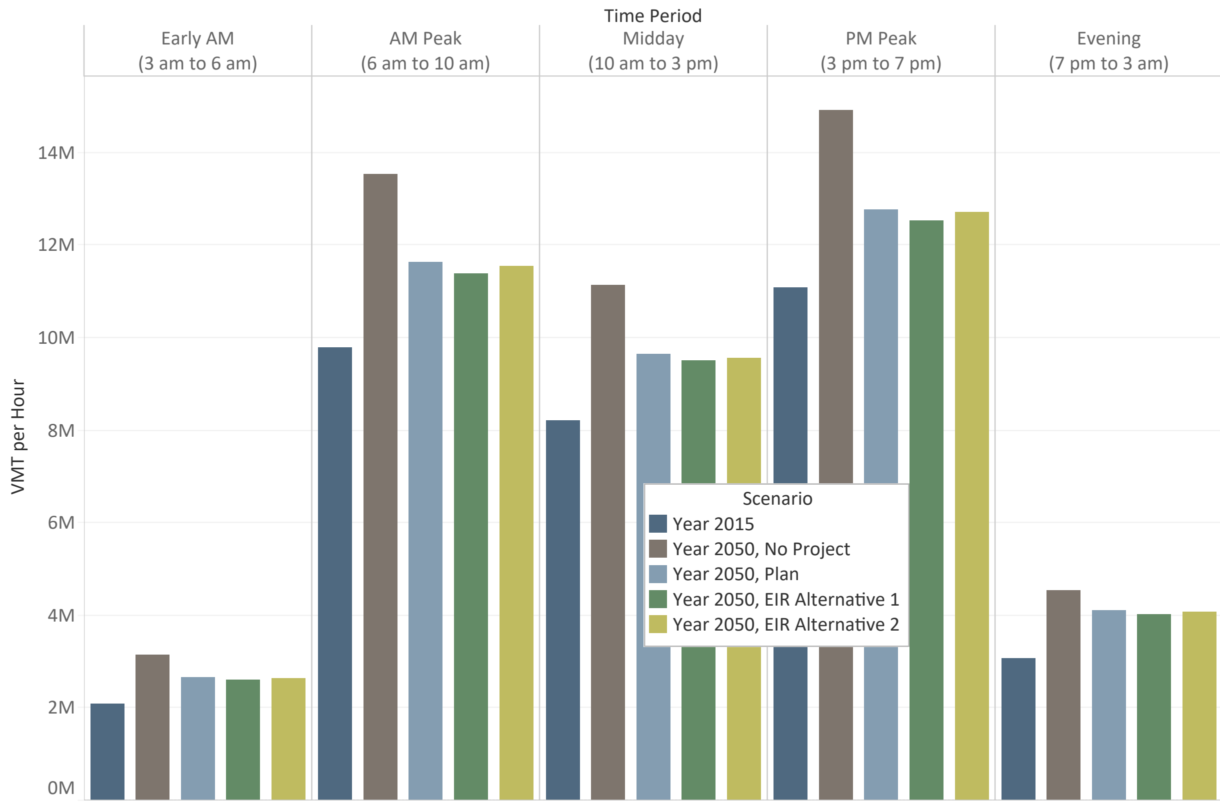
(1) the quantity assigned directly to the highway network; and

(2) the quantity (1) plus so-called "intra-zonal" VMT (i.e., travel that occurs at a geographic scale finer than the travel model's network representation), which is computed off-model

In this document, the VMT identified as (1) in the above list is presented.

Figure 37 first segments VMT into five time periods and then scales the VMT by the number of hours in each time period. The result is the intensity of VMT by time of day as well as the increase in VMT from 2015 to 2050. VMT drops significantly in the 2050 Plan and EIR Alternatives compared to 2050 No Project due to the strategies included in the Plan and EIR Alternatives, including road pricing and the commute trip reduction strategies, strategies to improve jobs/housing balance, and the other strategies included in the plan.

Figure 37. Vehicle miles traveled per hour by time period in 2050 across alternatives



Changes from Draft Forecasting and Modeling Report

Following the release of the Draft Environmental Impact Report and Draft Forecasting and Modeling Report for Plan Bay Area 2050, several assumptions underlying the Travel Modeling process were updated, and the scenarios were re-run. These fixes fell into two categories:

1) updates to modeling assumptions, and

2) network coding refinements for assorted projects to incorporate updated assumptions or correct errors

Additional detail on some of the more major updates is included below.

Refine "workers not working" assumptions

As discussed in the Draft Plan Bay Area 2050 Forecasting and Modeling Report, when staff incorporated updates to the estimate of telecommuters in the No Project scenario, staff applied data from the 2018-2019 Bay Area Transportation Study to estimate what proportion of workers who were not making a work tour (on the model simulation day) were telecommuting versus not going to work (due to alternative work schedules, or taking a vacation, sick or personal day). In reviewing this assumption, staff still considers it an appropriate assumption to apply to the 2015 model base year, but not to carry forward into future years. This is because the telecommute share is expected to rise, but the proportion of workers not going to work is not necessarily expected to change.

Therefore, staff updated the model assumption for future years to assume a fixed share of workers not working on the simulation day based upon the 2015 share: 10.8% of full-time workers and 20.6% of part-time workers. Assumptions about baseline telecommute rate (e.g., the share of workers telecommuting before the EN7 strategy was applied, described in Table 37 in the report) was not changed.

The impact on full-time workers for the No Project model runs is shown below. For the Draft EIR runs, the share of workers not working (in orange) increases slightly over time. With the implementation refinement, this share stays fixed for future years. This refinement affects all future year run, across all alternatives (No Project, Plan, EIR Alternative 1 and EIR Alternative 2).

Figure 38. Workers telecommuting, commuting, and not going to work in the Draft Plan (May 2021)

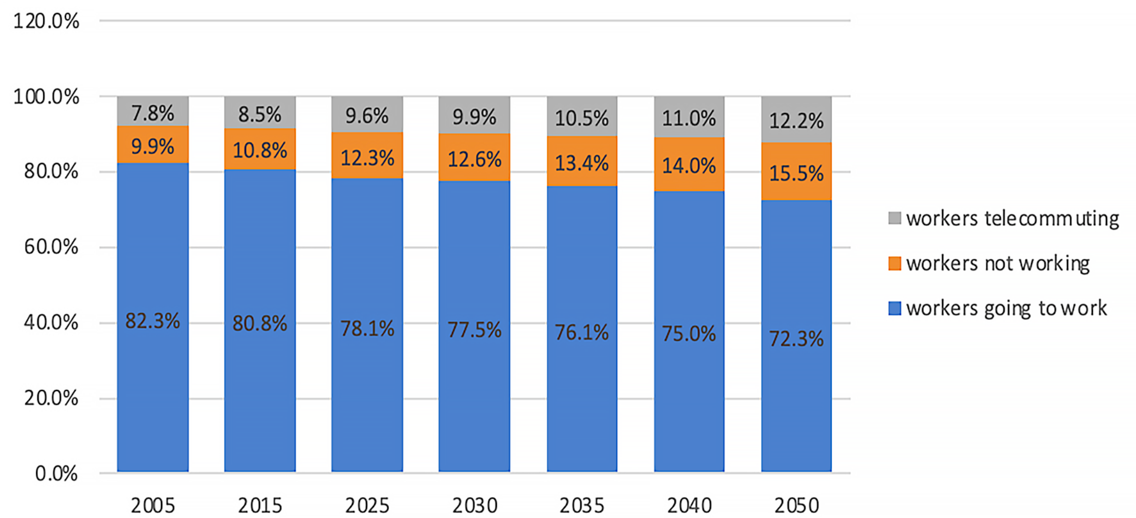
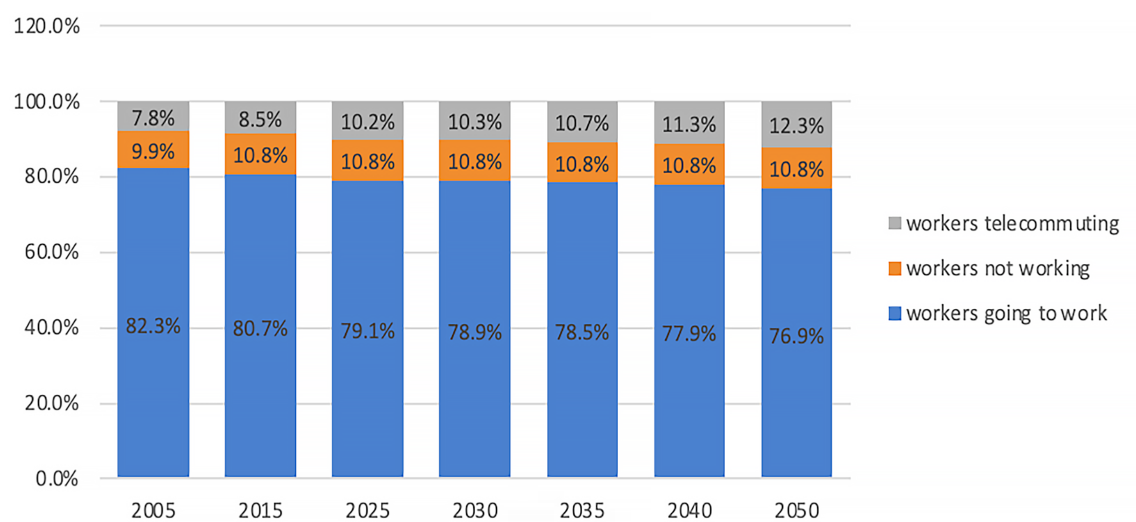


Figure 39. Workers telecommuting, commuting, and not going to work in the Plan (October 2021)



Update Transportation Network Company (TNC) wait time distribution configuration

The TNC wait time mean and standard deviation was reduced slightly in the highest density category. The wait time distribution was updated in the 2035 configuration, but not in the configuration for years after 2035; this omission has been corrected. This change has minor affects in model results because TNC trips represent a small share of trips.

Update Cube software to include fix for link-based fares which are used to represent zone-based express bus fares

For the Draft EIR travel model runs, 64-bit Cube 6.4.4 was used for transit assignment and skimming. This version does not assess link-based fares, which are used to add additional fares to the initial boarding fare when a certain link is traversed in a transit path. Link-based fares are a proxy for zone-based fares for express buses with a zone-based structure. Cube was updated to version 6.4.5, which fixed the bug in which link-based fares were not assessed. This fix had the effect of slightly decreasing express bus ridership for all model runs, but the effects were not significant. Staff verified the 2015 model run's transit ridership output was still valid with this fix.

Fix minor issues in base (2015) network

All the links in the 2015 network were scanned and the following fixes applied: a) reverse links that had different attribute values (distance, facility type, area type, city ID) b) a ramp that should be one-way instead of two-way on SR-4 in Antioch was fixed. Because the future year networks are built on top of the 2015 base network, these fixes affect the 2015 runs as well as all future year runs. However, the errors were all minor and so the effects on model results are likely insignificant.

Update internal/external travel assumptions

Travel Model 1.5 includes a representation of trips representing travel by non-residents who live outside the Bay Area and who drive into or out of the region on the typical simulated model day. For future forecast years, the traffic volumes at these gateway are assumed to be split into commute versus non-commute traffic; the assumed split is based on a comparison of Census Transportation Planning Product 2006-2010 and associated traffic volumes by subregion. For Plan Bay Area 2050, the commute share is not assumed to grow into the future, while the non-commute share of traffic is assumed to grow linearly based on past traffic volumes at the gateway. In 2019, these assumptions were updated slightly to move some forecasted growth between two gateways based on discussion with the neighboring Metropolitan Planning Organization, the Sacramento Area Council of Governments. Some model runs were found to be using the old configuration, and these were fixed. The effect of this fix is a minor change to traffic volumes at these gateways in future years.

Update Vehicle Buyback and Electric Vehicle Program assumptions

Discussed in the Off-Model Calculations section, several updates were made to this program, which is part of Strategy, EN8: Expand Clean Vehicle Initiatives. First, the program's funding was increased, from $3.7 billion to $5.1 billion through 2035, incentivizing buyback and purchase of 630,000 electric vehicles (from 462,000 electric vehicles assumed with the lower funding amount). Second, the analysis was updated to assume electric vehicle adoptions are a result of both the regional program and the state's program, the California Clean Vehicle Rebate Project, and greenhouse gas emissions reductions are shared between the programs.

Metropolitan Transportation Commission and Association of Bay Area Governments

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