Plan Bay Area

July 2013

Strategy for a Sustainable Region

Association of Bay Area Governments

Metropolitan Transportation Commission

Final Summary of Predicted Traveler Responses

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Summary of Predicted Traveler Responses

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1 Introduction

This supplementary report presents selected technical results from the analysis of alternatives performed in support of the Metropolitan Transportation Commission's (MTC's) and the Association of Bay Area Government's (ABAG's) 2013 Plan Bay Area environmental impact report (EIR). A brief overview of the technical methods used in the analysis as well as a brief description of the key assumptions made for each alternative precede the presentation of results.

2 Analytical Tools

To first describe the reaction of travelers to transportation projects and policies and to then quantify the impact of cumulative individual decisions on the Bay Area's transportation networks and environment, MTC maintains and applies an analytical tool known to transportation planners as a "travel model" (or "travel demand model", "travel forecasting model"). MTC's travel model is briefly described here, along with two supporting tools: a population synthesizer and a vehicle emissions model.

Population Synthesizer

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

Tools that create lists of households and persons for travel model simulations are known as population synthesizers. MTC's population synthesizer attempts to locate actual households described in the 2000 Decennial Census Public Use Micro-sample (PUMS) data (i.e., those who responded to the old "long forms" used by the Census Bureau to collect detailed household information) 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 totals more or less match those predicted by other Census summary tables (when synthesizing historical populations) or the land use projections made by ABAG and the Bay Area UrbanSim (UrbanSim) model[1] (when forecasting populations). For example, if ABAG/UrbanSim projects 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.

MTC's population synthesizer "controls" (i.e., minimizes the discrepancy between the synthetic population results and the historical Census results or ABAG/UrbanSim's forecasts) along the following dimensions:

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[1] A detailed discussion of the land use forecasting procedures are available in the companion supplementary report *Summary of Predicted Land Use Responses*.

1. Household "type", i.e. individual household unit or non-institutionalized group quarters (e.g., college dorm);
2. Household income category;
3. Age of head of household;
4. Number of persons in the household;
5. Number of children under age 17 in the household;
6. Number of employees in the household; and,
7. Number of units in the household's physical location (one or more than one, as in an apartment building).

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 One (version 0.3)*, released in spring 2012, calibrated to a 2000 base year, and validated against both year 2000 and year 2005 observed conditions[2].

Travel Model One is of the so-called "activity-based" archetype[3]. The model is a partial agent-based simulation in which the agents are the households and persons who reside in the Bay Area. The simulation is partial because it does not simulate the *individual* behavior of passenger and transit vehicles on roadways and transit facilities (the model system does simulate the behavior of *aggregations* of vehicles and transit passengers). In regional planning exercises such as the work described here, the travel model is used to simulate a typical weekday – when school is in session, the weather is pleasant, and no major accidents or incidents disrupt the transportation system.

The model operates on a synthetic population that includes households and persons which represent 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"[4] and, in so doing, burden 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[5] are as follows (organized sequentially):

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[2] Additional information is available here: http://analytics.mtc.ca.gov/foswiki/Main/Development.

[3] The term "activity-based" is not the most descriptive label for the travel model, but it has been adopted into transportation planning jargon as a label for the family of travel models of which *Travel Model One* belongs.

[4] An interactive map of these geographies is available here: http://geocommons.com/maps/130037.

[5] 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: http://en.wikipedia.org/wiki/Choice_modelling.

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 to attend school).
2. Household automobile ownership – Each household, given its location and socio-demographics, as well as each members' 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[6] 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[7] 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 more members of the same household traveling together) 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 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 them, and at what time to leave and return home.
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) decide 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 mode – 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

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

[7] Travel modelers 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); we use this jargon to communicate efficiently. We neither assume nor believe that all non-work/school related travel is non-mandatory or optional.

standard static user equilibrium procedures to the highway network. Transit trips are assigned to time-of-day-specific transit networks.

The *Travel Model One* 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 four-or-more axle vehicles.

Reconciling travel demand with available transportation supply is particularly difficult near the boundaries of planning regions because little is assumed to be known 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 is so-called "internal/external" travel) or to other boundary locations ("external/external" travel). MTC uses this typical approach and informs the process with Census (from the 2000 Decennial Census) journey-to-work flows, which are allocated via a 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 the Bay Area's airports is represented with static (across alternatives), year-specific vehicle trip tables. These trip tables are based on survey data[8] collected in 2006 and planning information developed as part of MTC's *Regional Airport Planning Study*[9].

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 emitted criteria pollutants as well as carbon dioxide (used as a proxy for all greenhouse gases). For the current analysis, MTC used the EMFAC2011 version of the California Air Resources Board emissions factor software[10].

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8 Additional information is available here: http://mtc.ca.gov/planning/air_plan/2006_Air_Pass_Survey_Final_Report.pdf.

9 Additional information is available here: http://mtc.ca.gov/planning/air_plan/.

10 Additional information is available here: http://www.arb.ca.gov/msei/msei.htm.

3 Input Assumptions

In total, nineteen scenarios were simulated and selected results are presented and discussed in the remainder of this document. Four *categories* of scenarios are included, as follows: historical, no action, planned action, and alternative actions. Historical scenarios are labeled by their year and include Year 2005 and Year 2010. The no action alternative is referred to as "No Project"; No Project simulations were performed for 2020, 2035, and 2040. The planned action is referred to as the "Proposed Plan" (often abbreviated as "Plan") alternative; Proposed Plan simulations were performed for 2015, 2020, 2030, 2035, and 2040. Three separate alternative scenarios are included and are labeled "Transit Priority", "Enhanced Network of Communities" (occasionally abbreviated henceforth as "Enhanced Communities" or "Enhanced"), and "Environment, Equity, and Jobs" ("EEJ"). Year 2020, 2035, and 2040 simulations were conducted for each of these alternatives. Table 1 below identifies the simulation years for each of the alternatives. The various simulation years serve different purposes: historical years demonstrate the model's ability to adequately replicate reality[11] and provide the reader data for a familiar scenario; the California Air Resources Board established greenhouse gas reduction targets for 2020 and 2035; the transportation plan, as guided by federal regulations, extends to 2040; and, air quality regulations require 2015 and 2030 simulations.

The above scenarios differ across four dimensions, namely: land use, roadway supply, transit supply, and prices. By land use, we mean the locations of households and jobs (of different types). Roadway supply refers to the network upon which automobiles, trucks, transit vehicles, bicycles, and pedestrians travel. Transit supply refers to the facilities upon which transit vehicles travel (the roadway, along with rail lines, ferry routes, and other dedicated infrastructure), as well as the stop locations, route, and frequency of service on each facility. Prices include the monetary fee users are charged to board transit vehicles, cross bridges, operate and park private vehicles and use express (also known as high occupancy toll) lanes.

In the remainder of this chapter, each of the six scenarios (the rows in Table 1) is discussed, organized by these four dimensions; additional notes on "other assumptions" concludes the section. This organization should allow the reader to compare the input assumptions across scenarios.

[11] Details of this "validation" process are available here: http://analytics.mtc.ca.gov/foswiki/Main/Development.

TABLE 1: SIMULATIONS BY YEAR AND ALTERNATIVE

Alternative	*Simulation Year*						
	2005	*2010*	*2015*	*2020*	*2030*	*2035*	*2040*
Historical	✓	✓					
No Project				✓		✓	✓
Proposed Plan			✓	✓	✓	✓	✓
Transit Priority				✓		✓	✓
Enhanced Communities				✓		✓	✓
Environment, Equity, and Jobs				✓		✓	✓

Land Use

Detailed information regarding the land development patterns is available in a companion supplementary report, *Summary of Predicted Land Use Responses,* available on www.onebayarea.org. 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 ABAG (control totals and distribution details) and the UrbanSim model (distribution details) are run through the MTC population synthesizer as described above. The journey from control totals through UrbanSim and through the population synthesizer causes minor inconsistencies between the ABAG-estimated regional control totals and the totals implied by the synthetic population (a more detailed discussion of these differences is included as an appendix to the *Summary of Predicted Land Use Responses* supplementary report). These inconsistencies are caused by: (i) UrbanSim, which fails to simulate the development of enough housing opportunities for the expected population (given unlimited time and resources, the model could be tuned to precisely replicate the control totals of developed housing provided by ABAG); (ii) expediency, which limits the time provided to the population travel model's synthesizer software to find the optimal solution, i.e. the synthetic population that best matches the UrbanSim or ABAG distributions; and, (iii) inconsistency, between the zone-specific control totals, as provided by UrbanSim or ABAG, and base year data, as provided by the Census, meaning there may not be a synthetic population that can satisfy all of the control totals. These inconsistencies are quantified and presented for years 2005, 2010, 2020, and 2040 in Table 2 below – similar inconsistencies exist for the other forecast years. The inconsistencies are very small for the Proposed Plan and Enhanced Alternatives; the distribution of development for these alternatives comes from a simple allocation scheme developed by ABAG. The inconsistencies are a bit larger for the No Project, Transit Priority, and EEJ Alternatives; these alternatives rely on UrbanSim for their distribution.

TABLE 2: DEMOGRAPHIC STATISTICS OF CONTROL AND SIMULATED POPULATIONS

Alternative	*Year*	*Households*				*Population*		
		ABAG Results		*Synthetic Population*	*Percent Difference*[†]	*ABAG Results*	*Synthetic Population*	*Percent Difference*
		Households	*Group Quarters*					
Historical	2005	2,583,077	144,597	2,720,722	-0.3%	7,069,469	7,007,634	-1.3%
Historical	2010	2,608,023	147,683	2,732,722	-0.8%	7,150,741	7,053,334	-1.4%
No Project	2020	2,833,671	93,971	2,894,543	-1.1%	7,718,418	7,696,761	-0.3%
Proposed Plan	2020	2,837,715	93,956	2,925,108	-0.2%	7,718,420	7,697,101	-0.3%
Transit Priority	2020	2,833,671	93,971	2,897,715	-1.0%	7,718,418	7,708,472	-0.1%
Enhanced	2020	2,871,765	93,976	2,960,947	-0.2%	7,820,887	7,799,899	-0.3%
EEJ	2020	2,833,671	93,971	2,896,231	-1.1%	7,718,418	7,698,249	-0.3%
No Project	2040	3,308,120	110,665	3,281,324	-3.0%	9,195,569	8,709,541	-5.3%
Proposed Plan	2040	3,308,111	110,627	3,411,297	-0.2%	9,195,546	9,133,090	-0.7%
Transit Priority	2040	3,308,120	110,665	3,357,898	-1.8%	9,195,569	8,918,832	-3.0%
Enhanced	2040	3,431,742	110,626	3,534,957	-0.2%	9,535,023	9,471,803	-0.7%
EEJ	2040	3,308,120	110,665	3,355,942	-1.8%	9,195,569	8,903,747	-3.2%

† 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 1 shows the distribution of person types for the historical scenarios and the Proposed Plan alternative, from years 2005 to 2040. Interesting aspects of these distributions, which are driven by assumptions embedded in ABAG's land use forecasts, are as follows:

- The share of full-time workers peaks in 2020;
- The share of retired workers steadily increases from 2005 to 2040; and,
- The share of non-working adults drops sharply from 2010 to 2020.

Figure 2 shows the distribution of person types across the five forecast year alternatives for year 2040. As noted above, the control totals for the five alternatives are slightly different. When taken through the population synthesizer, one result is that the alternatives derived from UrbanSim (the No Project, Transit Priority, and EEJ alternatives) have a slightly higher share of full- and part-time workers and a slightly lower share of non-workers and college students than the Proposed Plan and Enhanced Alternatives. The shares for the other person types are highly similar.

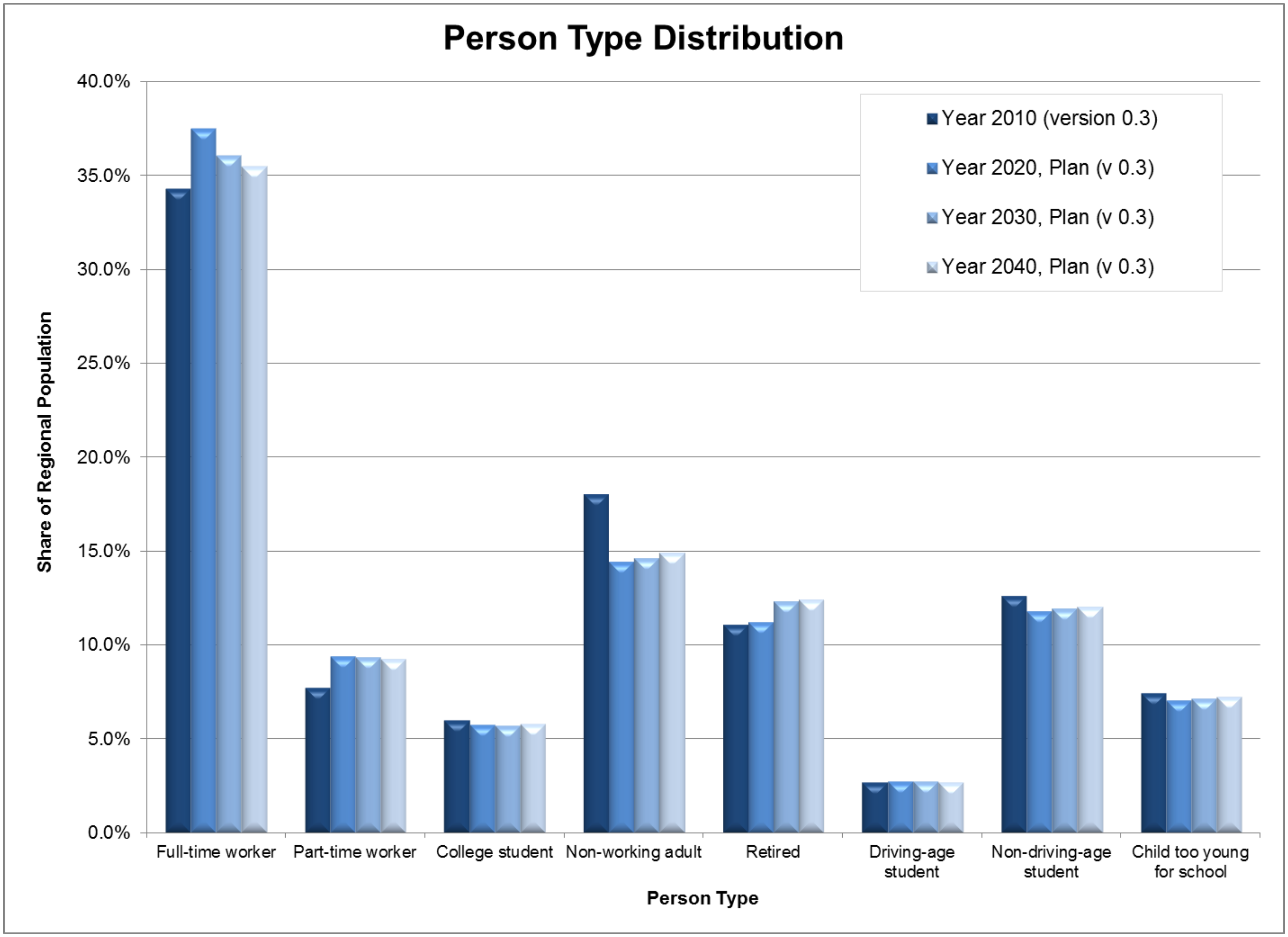

FIGURE 1: HISTORICAL AND FORECASTED PERSON TYPE DISTRIBUTIONS FOR PROPOSED PLAN ALTERNATIVE

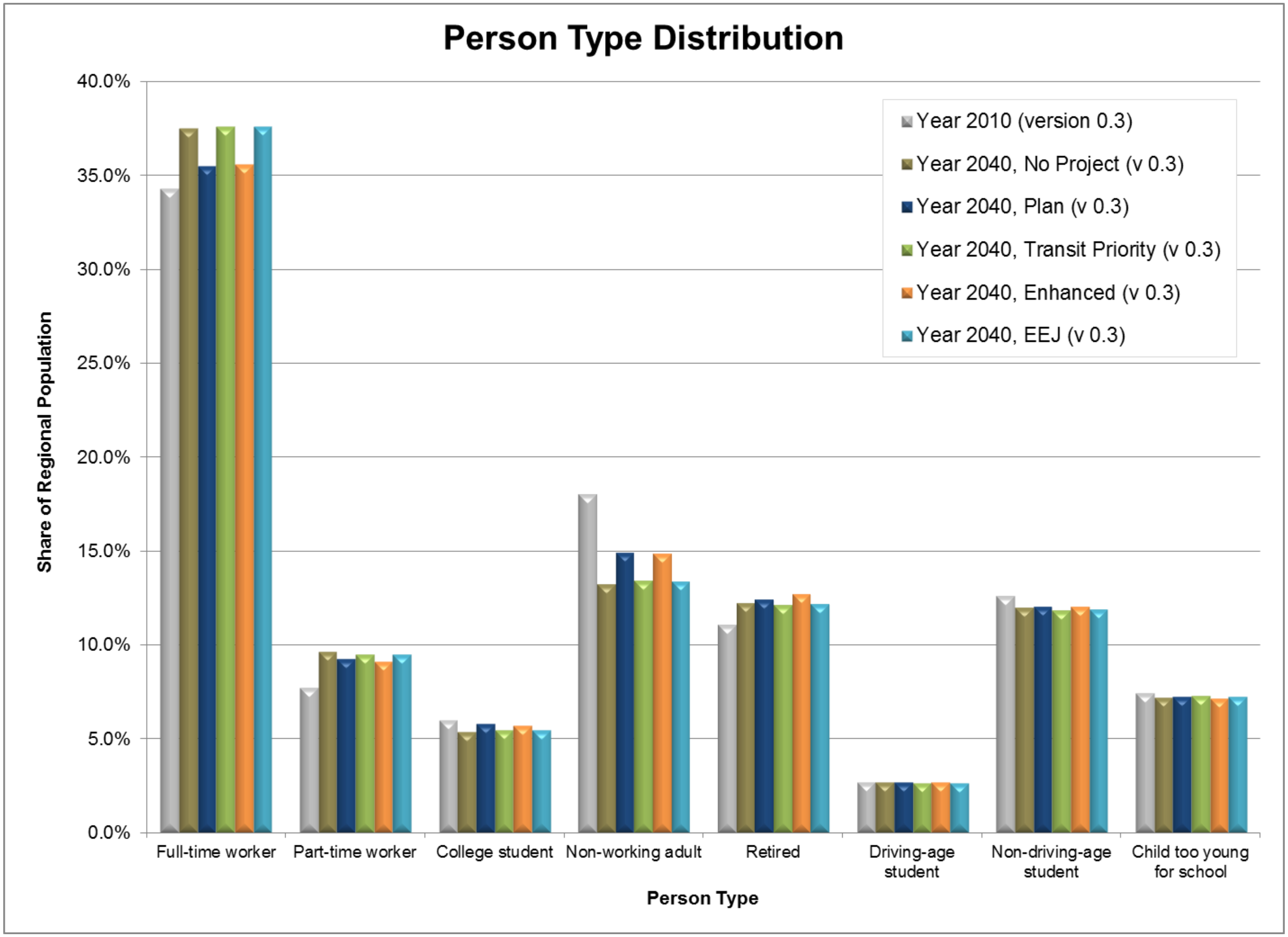

FIGURE 2: YEAR 2040 PERSON TYPE DISTRIBUTIONS

Roadway Supply

Table 3 below summarizes the assumptions made in regards to the roadway network in each of the scenario categories.

The historical scenarios for 2005 and 2010 have a representation of roadways that reflect the 2005 and 2010 infrastructure.

The No Project alternative includes projects that are either in place as of 2013 or are "committed" per MTC *Resolution 4006*. The Proposed Plan alternative includes the projects included in the transportation investment strategy, which is discussed in detail elsewhere.

The Transit Priority alternative roadway networks (for each scenario year) are identical to the Proposed Plan alternative network with one exception: the Regional Express Lane network is reduced. Specifically, the segments of the express lane network on (a) Interstate 80 from the intersection with Interstate 505 to the Yolo County line and (b) Interstate 580 from the Vasco Road interchange to the San Joaquin County line have been eliminated. Please see Figure 3 for a graphical depiction of this change in year 2035. The timing of the express lane build out is the same in the Proposed Plan and Transit Priority alternatives.

The Enhanced Network of Communities alternative has the same roadway network as the Proposed Plan alternative.

The Environment, Equity, and Jobs alternative starts with the No Project alternative roadway network, then adds the Proposed Plan alternative's bus rapid transit (BRT) infrastructure and freeway performance initiative (FPI) improvements. No other uncommitted roadway projects are included in the EEJ alternative. In the travel model simulation, buses traveling over BRT infrastructure move faster through the roadway network and roadways with FPI treatments (e.g., ramp metering, signal coordination) are assumed to have an increased effective operating capacity, which leads to higher speeds (all else equal) for automobiles and transit vehicles.

TABLE 3: ROADWAY SUPPLY ASSUMPTIONS BY ALTERNATIVE

Alternative	*Roadway Assumptions*
Historical	As built in the scenario year
No Project	Existing plus committed projects
Proposed Plan	Proposed Plan alternative
Transit Priority	Proposed Plan alternative with reductions to express lane network
Enhanced Communities	Proposed Plan alternative
Environment, Equity, and Jobs	Existing plus committed with Proposed Plan alternative's bus-rapid transit infrastructure and freeway performance initiative improvements

A graphical depiction of the changes in the roadway network is presented in Figure 4 below. 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 2040 relative to the year 2010. On net, San Francisco County shows a decrease in lane-miles, as some roadway segments are converted to dedicated bus ways. Figure 5 shows the change in lane-miles over time for the Proposed Plan alternative.

All (committed)
Plan, Transit Priority and Enhanced
Plan and Enhanced

FIGURE 3: YEAR 2035 PROPOSED EXPRESS LANE NETWORKS

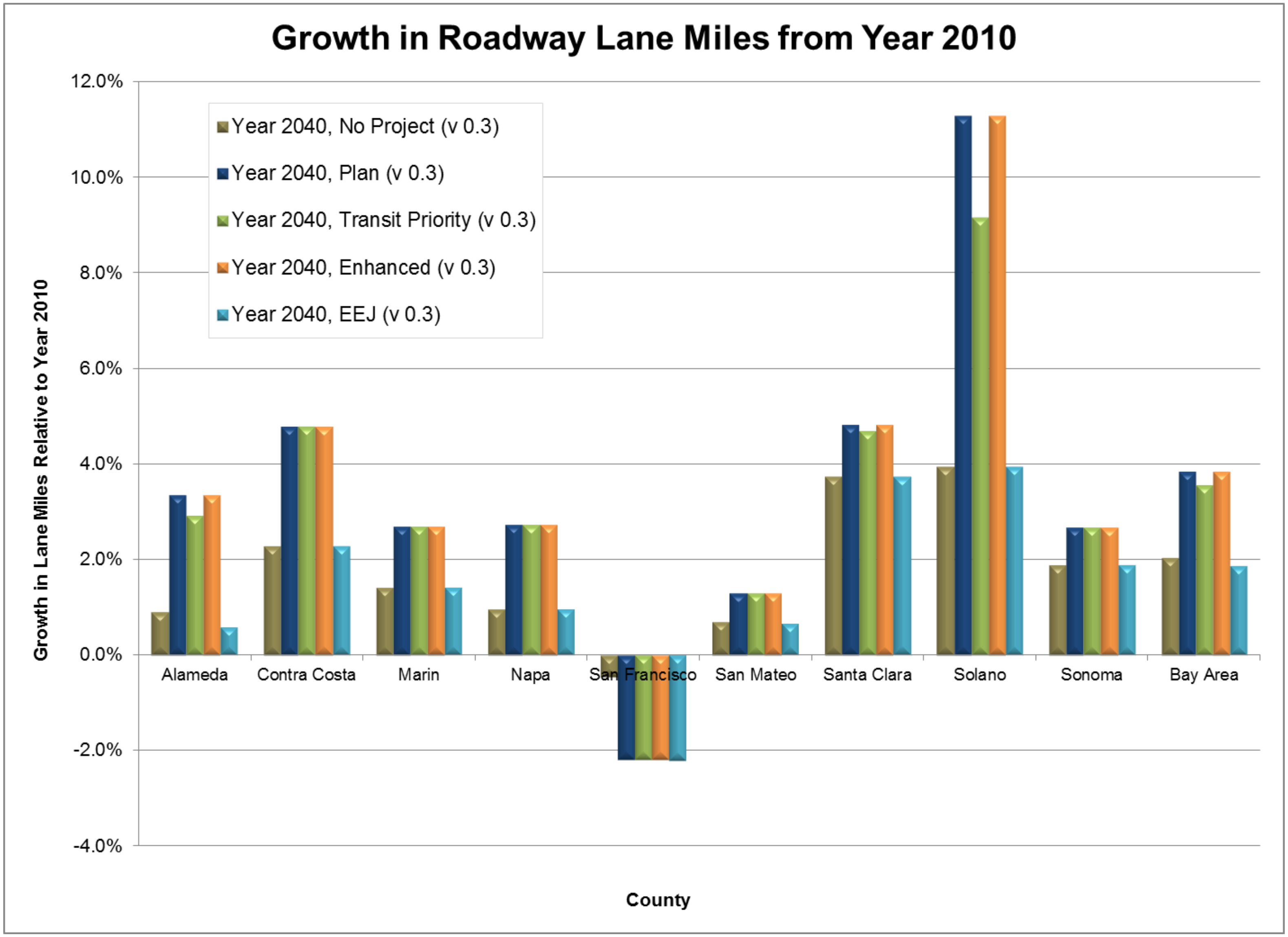

FIGURE 4: YEAR 2040 GROWTH IN ROADWAY LANE MILES AVAILABLE TO AUTOMOBILES RELATIVE TO 2010

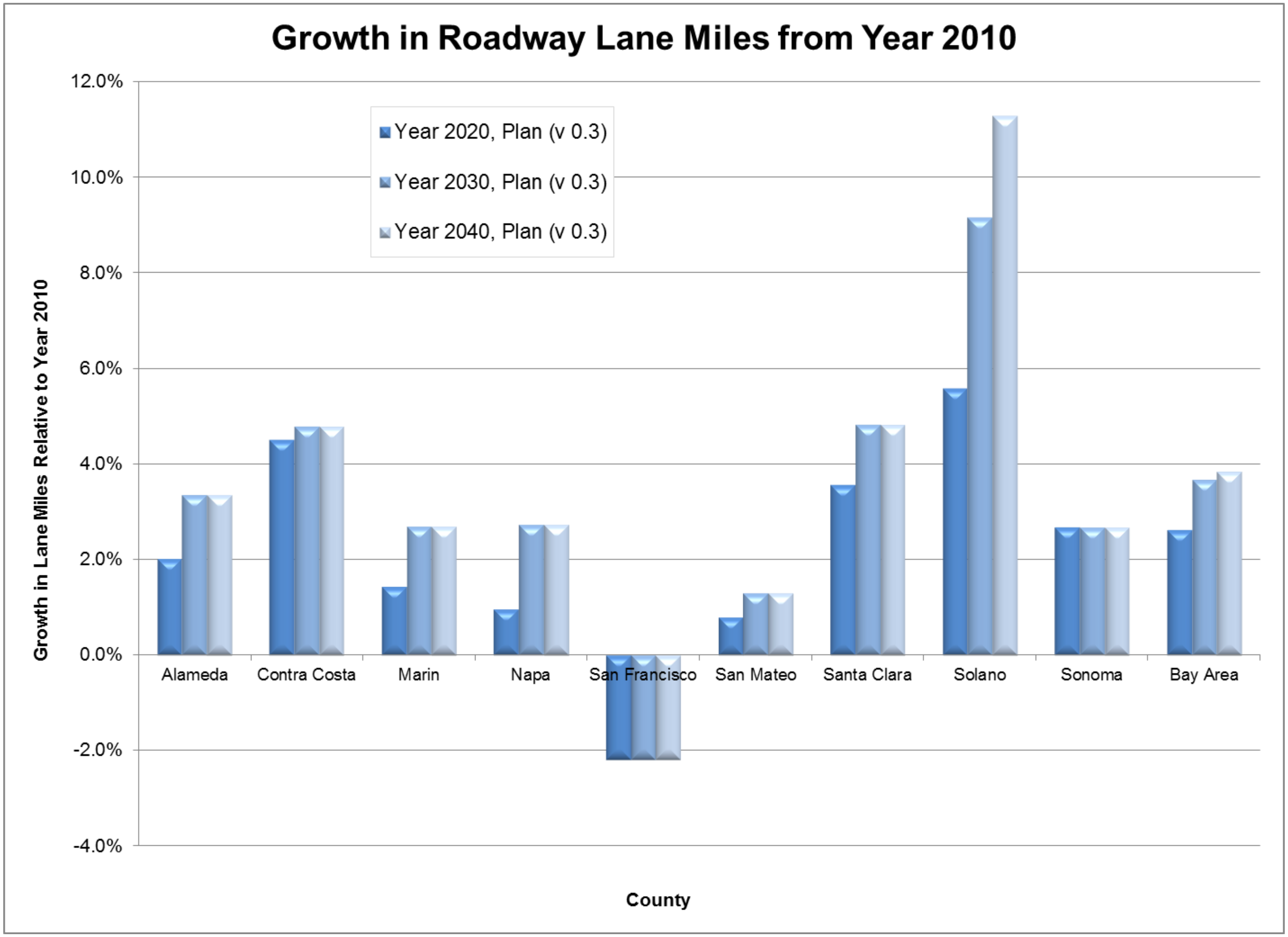

FIGURE 5: GROWTH IN ROADWAY LANE MILES AVAILABLE TO AUTOMOBILES FOR PROPOSED PLAN ALTERNATIVE

Transit Supply

Table 3 and Table 4 below summarize the assumptions made in regards to the transit network in each of the scenario categories.

The historical scenarios for 2005 and 2010 have a representation of transit service that reflect service in 2005 and 2010.

The No Project alternative begins with 2010 service levels and adds in projects that are committed per MTC's *Resolution 4006*. The Proposed Plan alternative also begins with the 2010 service levels and adds in the committed projects as well as the projects included in the transportation investment strategy.

The Transit Priority alternative begins with the Proposed Plan alternative and includes additional service improvements for Alameda/Contra Costa County Transit (AC Transit) and the Bay Area Rapid Transit service (BART) for all simulation years on or after 2020. These changes are summarized in Table 5 and are intended to represent cost effective service changes consistent in nature with the recent service changes made by the Santa Clara Valley Transportation Authority (VTA) following their comprehensive operations analysis. Similar efficiency-focused changes for San Francisco Municipal Railways (Muni) are included in the Proposed Plan alternative.

The Enhanced Network of Communities alternative has the same transit network as the Proposed Plan alternative.

The Environment, Equity, and Jobs alternative begins with the Transit Priority alternative and adds in service improvements for AC Transit, VTA, San Mateo County Transit (SamTrans), Marin Transit, Golden Gate Transit, Livermore Amador Valley Transit Authority (LAVTA), County Connection (Central Contra Costa County), Santa Rosa CityBus, and Sonoma County Transit. These improvements are made for all simulation years on or after 2020 and are summarized in Table 6.

A graphical depiction of the changes in the transit service is presented in Figure 6 below. The chart shows the change in seat-miles (e.g., a one-mile segment of a bus with forty seats is forty-seat miles) in year 2040 relative to the year 2010 across alternatives; Figure 7 shows the change in seat-miles over time for the Proposed Plan Alternative.

TABLE 4: TRANSIT SUPPLY ASSUMPTIONS BY ALTERNATIVE

Alternative	*Transit Service Assumptions*
Historical	As built in the alternative year
No Project	Year 2010 service plus committed projects
Proposed Plan	Year 2010 service plus projects in the transportation plan
Transit Priority	Proposed Plan alternative plus service aimed at improving the operational efficiency of BART and AC Transit
Enhanced Communities	Proposed Plan alternative
Environment, Equity, and Jobs	Transit Priority alternative plus service aimed at improving the connection between low income communities and jobs

TABLE 5: CHANGES TO AC TRANSIT AND BART SERVICE IN TRANSIT PRIORITY ALTERNATIVE

Operator	*Route(s)*	*Changes*
BART	All	Core routes operate at 12-minute frequencies during commute hours and additional short-run routes (Pleasant Hill to Daly City; Berryessa to 24th St Mission; South Hayward to Daly City) operate during commute hours
AC Transit	11, 12, 14, 18, 20, 21, 22, 25, 31, 40, 45, 46, 49, 51A, 51B, 52, 54, 57, 62, 65, 67, 72R, 73, 74, 76, 85, 86, 97, 98, 99, 210	Improved service frequencies throughout the day

TABLE 6: EEJ ALTERNATIVE TRANSIT FREQUENCY IMPROVEMENTS

Operator & Service	*Route(s)*	*Changes*
BART	Same as Transit Priority, as shown in Table 5	
AC Transit Local	Same as Transit Priority, as shown in Table 5	
AC Transit Transbay	FS, J, O, OX, P, SB, U, V, W	Improved service frequencies during commute hours
County Connection	1, 4, 6, 10, 11, 14,15, 17, 20	Improved service frequencies throughout the day
Golden Gate Transit	70	Improved service frequency during commute hours
LAVTA Local	8, 10, 12, 14, 15	Improved service frequencies throughout the day
LAVTA Express	70	Improved service frequencies throughout the day
Marin Transit	17, 22, 23, 29, 35, 36, 71	Improved service frequencies throughout the day
SamTrans Local	110, 120, 121, 122, 130, 250, 260, 292, 296	Improved service frequencies throughout the day
SamTrans Express	KX	Improved service frequencies throughout the day
Santa Rosa CityBus	1, 9, 10, 14	Improved service frequencies throughout the day
Sonoma County Transit	20, 30, 44/48, 62	Improved service frequencies throughout the day
VTA light Rail	900, 901, 902	Trains operate at 8 minute frequencies during commute hours and 10 minute frequencies during the midday
VTA Local	25, 26, 40, 46, 51, 52, 53, 54, 55, 66, 70, 71, 72, 73, 201	Improved service frequencies throughout the day

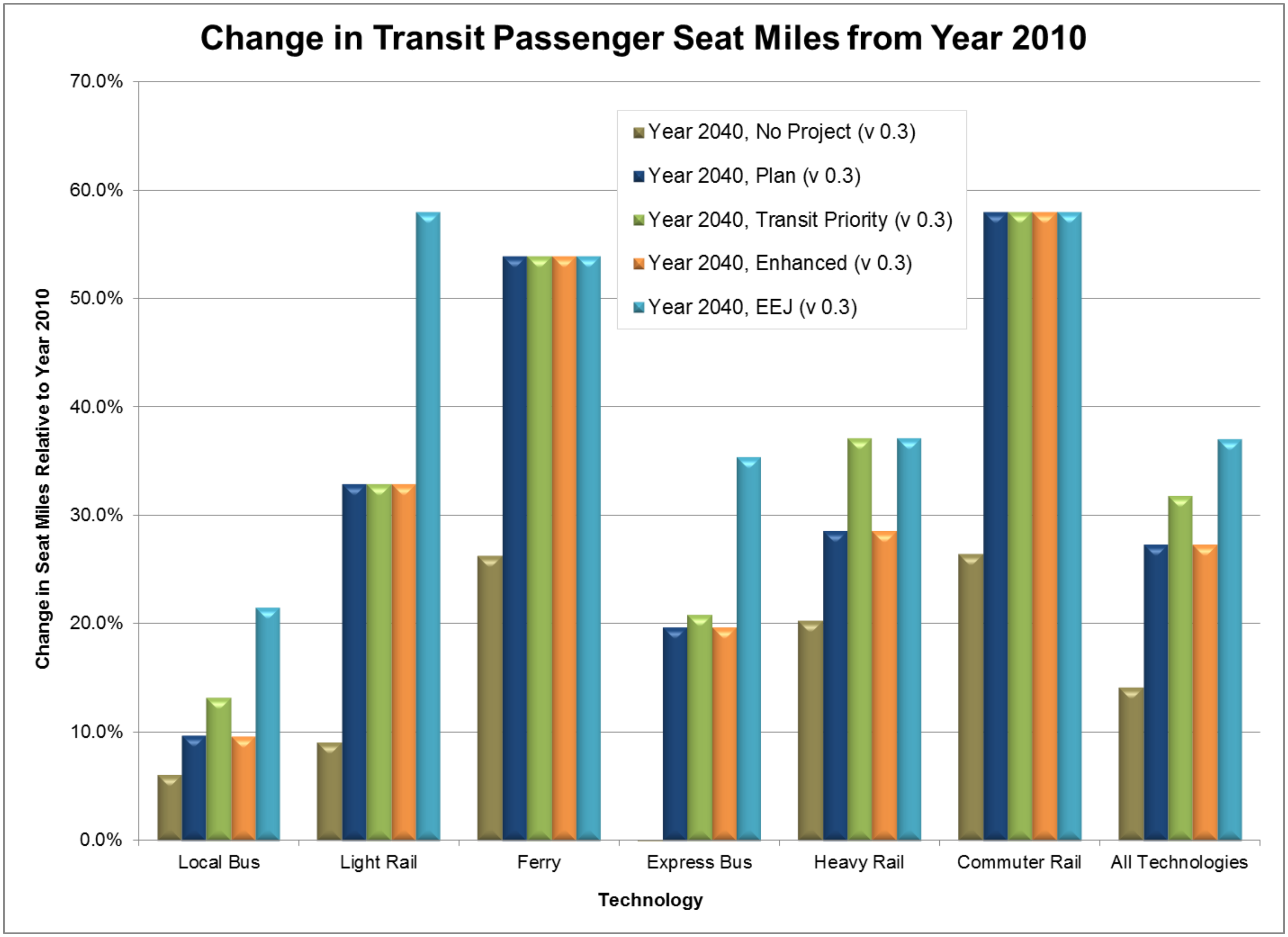

FIGURE 6: YEAR 2040 GROWTH IN TRANSIT PASSENGER SEAT MILES FROM 2010

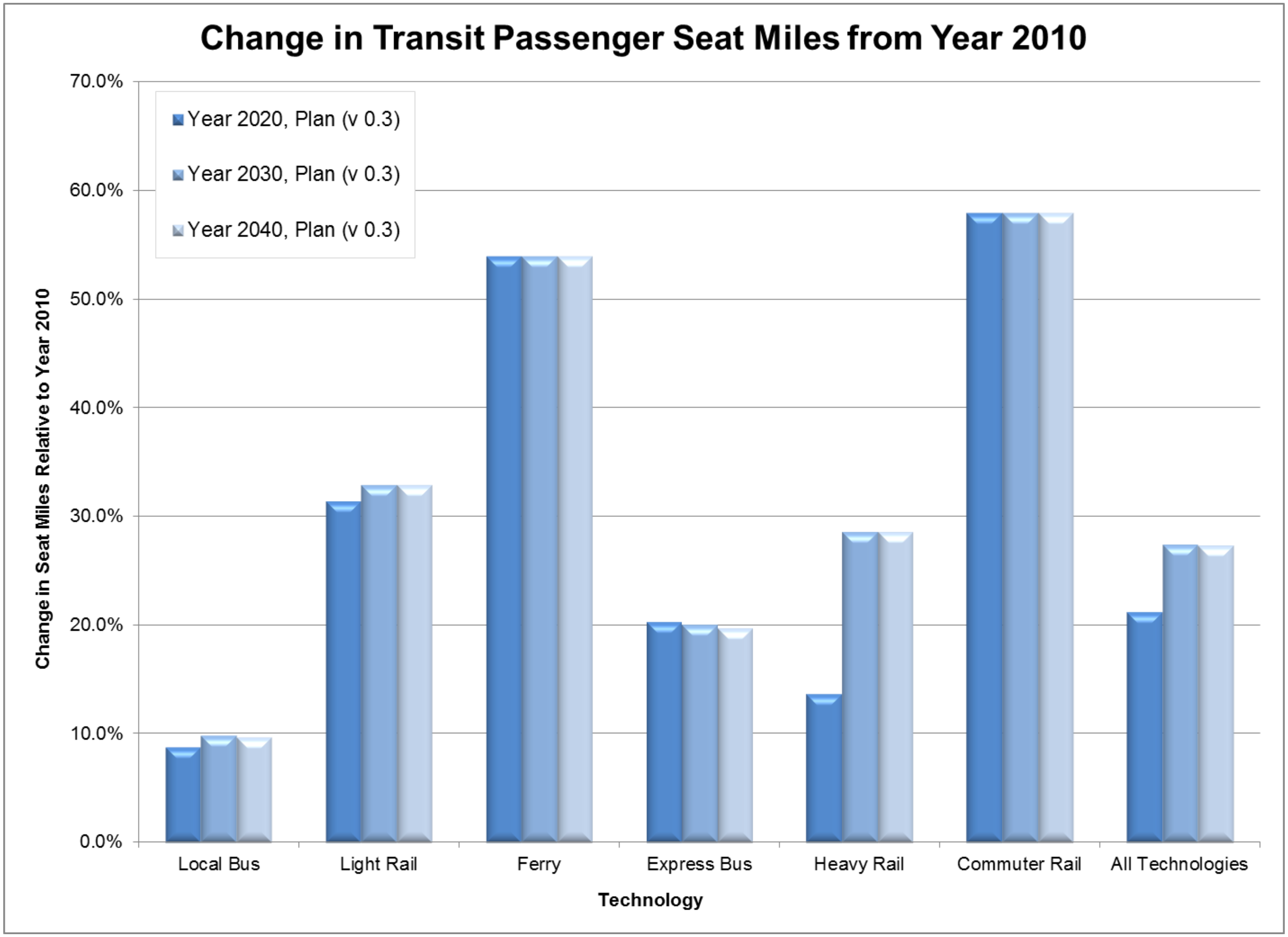

FIGURE 7: GROWTH IN TRANSIT PASSENGER SEAT MILES FOR PROPOSED PLAN ALTERNATIVE

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 determinant 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, as follows: (i) driving, which would take 40 minutes (roundtrip) and cost $10 for parking; or, (ii) taking transit, which would take 90 minutes (roundtrip) 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 an "expensive" (in terms of staff time and/or consultant resources) process, it is done infrequently, which, in effect, "locks in" the dollar year in which prices are input to the travel model. In order 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) current year dollars, to give the reader an intuitive sense as to the scale 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, as follows: (i) bridge tolls; (ii) express lane tolls; (iii) transit fares; (iv) perceived automobile operating cost and vehicle miles traveled tax; (v) parking charges; 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 TRAVEL 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 8). The means of these distributions are a function of each traveler's household income. 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 alternatives.

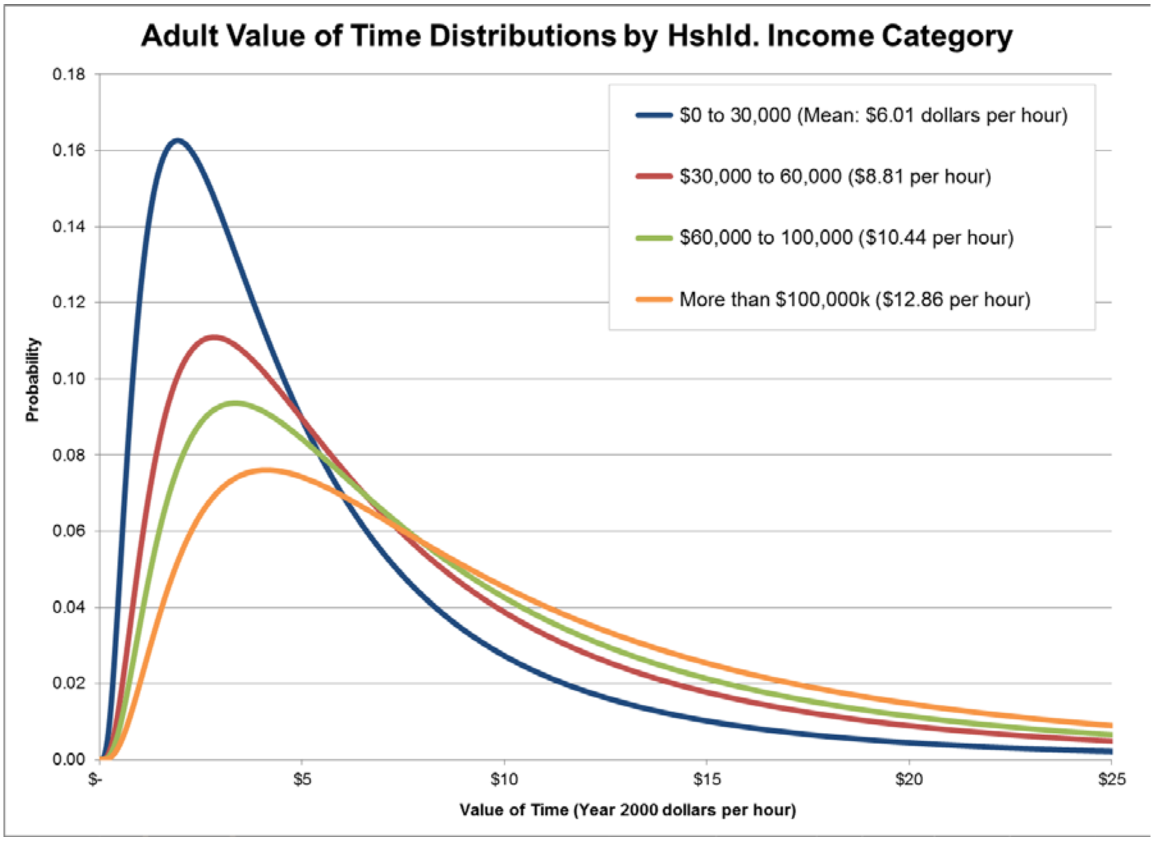

FIGURE 8: ADULT VALUE OF TIME DISTRIBUTION BY HOUSEHOLD INCOME

BRIDGE TOLLS

The historical scenarios for 2005 and 2010 use the bridge toll schedules in place at these historical points in time. Common bridge tolls assumed in the Year 2010 scenario are shown below in Table 7. Please note that Table 7 includes the price of tolls in year 2010 expressed in both year 2000 and year 2010 dollars.

TABLE 7: YEAR 2010 COMMON PEAK PERIOD BRIDGE TOLLS†

Bridge	*2-axle, single-occupant toll*		*2-axle, carpool* toll*	
	$2000	*$2010*	*$2000*	*$2010*
San Francisco/Oakland Bay Bridge	$4.82	$6.00	$2.01	$2.50
Antioch Bridge	$4.02	$5.00	$2.01	$2.50
Benicia/Martinez Bridge	$4.02	$5.00	$2.01	$2.50
Carquinez Bridge	$4.02	$5.00	$2.01	$2.50
Dumbarton Bridge	$4.02	$5.00	$2.01	$2.50
Richmond/San Rafael Bridge	$4.02	$5.00	$2.01	$2.50
San Mateo Bridge	$4.02	$5.00	$2.01	$2.50
Golden Gate Bridge	$4.82	$6.00	$2.41	$3.00

† The full toll schedule includes off-peak tolls and tolls for 3- or more axle vehicles. * Carpools are defined as either two-or-more- or three-or-more-occupant vehicles, depending on the bridge, and only receive a discount during the morning and evening commute periods (source: bata.mtc.ca.gov; goldengatebridge.org).

The No Project and Proposed Plan alternatives assume the toll schedule in place as of July 1, 2012. This schedule is consistent with the year 2010 tolls presented in Table 7, though there are differences in the tolls for multi-axle vehicles, which are not shown in Table 7[12]. The toll schedules do not change in the forecast years. By keeping the toll prices constant (when expressed in real dollars), we are explicitly assuming that bridge tolls will be as "expensive" as they are today, when measured relative to parking fees, travel time, and transit fares. Said another way, bridge tolls are assumed to increase with inflation.

The Transit Priority, Enhanced Network of Communities, and Environment, Equity, and Jobs alternatives assume increases in the peak period single-occupant vehicle San Francisco/Oakland Bay Bridge toll. Specifically, these alternatives assume a real increase of $1 ($2010) in 2024 and another $1 in 2029. As such, the peak period Bay Bridge toll increases, when measured in year 2010 dollars, from $6 to

[12] Complete details are available here: http://bata.mtc.ca.gov/tolls/schedule.htm.

$7 in 2024 and from $7 to $8 in 2029. The tolls for all other bridges are the same as in the Proposed Plan alternative.

The Proposed Plan, Transit Priority, Enhanced Network of Enhanced Communities, and Environment, Equity, and Jobs alternatives each assume a new toll of $5 ($2010) for passenger vehicles leaving Treasure Island during the morning and evening commute periods. The assumptions for each alternative are summarized in Table 8.

TABLE 8: BRIDGE TOLL ASSUMPTIONS BY ALTERNATIVE

Alternative	*Bridge Toll Assumptions*
Historical	Per scenario year schedule
No Project	Schedule as of July 1, 2012
Proposed Plan	No Project plus Treasure Island toll
Transit Priority	Proposed Plan plus increased peak period Bay Bridge toll
Enhanced Communities	Proposed Plan plus increased peak period Bay Bridge toll
Environment, Equity, and Jobs	Proposed Plan plus increased peak period Bay Bridge toll

EXPRESS LANE 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 lanes. To exploit this functionality, the analyst must assign a travel price by time of day and vehicle class on each express lane link in the network. To efficiently and transparently simulate the impacts of the express lanes on behavior, we segmented the express lane network in the Proposed Plan alternative into about fifty corridors, with each corridor receiving a time-of-day-specific per mile toll fee. To illustrate the detail involved in this coding, Table 9 presents each corridor's limits, number of lanes, occupancy rules ("3+" means vehicles with three-or-more occupants can use the express lane without paying a toll), and commute period/commute direction per mile fee for the year 2035 simulation. Please note that the prices presented in Table 9 are not optimal – meaning, MTC did not analyze each corridor iteratively to find the price that maximized a pre-defined operational goal. Rather, the prices are adjusted a handful of times in an attempt to keep congestion low and utilization high. Importantly, the prices are held constant over four-hour morning (6 to 10 am) and evening (4 to 7 pm) commute periods. MTC's travel model assumes that congestion is uniform over the entire four-hour commute periods. We know this is not true, but make this assumption as a simplification. The peak one-hour within the four-hour commute period would require, in most corridors, a higher toll than those listed in Table 9.

Please see the discussion on Roadway Supply for details regarding the limits of the express lane networks across alternatives. The prices listed in Table 9 are applied in each of the year 2035 and 2040 alternatives where the express lanes are operational (prices differ in the year 2010, 2015, and 2020 scenarios).

TABLE 9: YEAR 2035 PROPOSED PLAN ALTERNATIVE EXPRESS LANE TOLL PRICES

Roadway	*DIR*	*From*	*To*	*Lanes*	*Occu-pancy Rules*[†]	*Cents per mile ($2000)*	*Cents per mile ($2010)*
I-80	WB	I-680	Bay Bridge	1	3+	13.5	17.0
	EB	Bay Bridge	I-680	1	3+	7.0	8.8
I-80	WB	Yolo County Line	I-680	1	3+	0.0	0.0
	EB	I-680	Yolo County Line	1	3+	0.0	0.0
I-880	NB	US 101	Oakland International	1	3+	8.0	10.1
	NB	CA 237	Mission Blvd	2	3+	8.0	10.1
	NB	Mission Blvd	Oakland International	1	3+	8.0	10.1
	SB	Oakland International	Mission Blvd	1	3+	12.0	15.1
	SB	Mission Blvd	CA 237	2	3+	12.0	15.1
	SB	CA 237	US 101	1	3+	12.0	15.1
CA-17	NB	CA 85	US 101	1	3+	0.5	0.6
	SB	US 101	CA 85	1	3+	3.0	3.8
US 101	NB	I-880	Santa Clara County Line	2	3+	1.5	1.9
	NB	Santa Clara County Line	Whipple	1	3+	2.0	2.5
	SB	Whipple	Santa Clara County Line	1	3+	0.5	0.6
	SB	Santa Clara County Line	I-880	2	3+	1.5	1.9

US 101	NB	San Benito County Line	Cochrane	1	3+	0.0	0.0
	NB	Cochrane	I-880	2	3+	0.0	0.0
	SB	I-880	Cochrane	2	3+	0.0	0.0
	SB	Cochrane	San Benito County Line	1	3+	0.0	0.0
CA 85	NB	US 101	I-280	1	3+	0.0	0.0
	NB	I-280	SR 87	2	3+	0.0	0.0
	NB	SR 87	US 101	1	3+	0.0	0.0
	SB	US 101	SR 87	1	3+	0.0	0.0
	SB	SR 87	I-280	2	3+	0.0	0.0
	SB	I-280	US 101	1	3+	0.0	0.0
I-680	SB	I-580	US 101	1	3+	10.0	12.6
	NB	US 101	I-580	1	3+	2.0	2.5
I-680	SB	I-80	I-580	1	3+	6.0	7.6
	NB	I-580	I-80	1	3+	3.7	4.7
I-580	WB	San Joaquin County Line	I-680	1	3+	2.5	3.2
	EB	I-680	Tassajara	1	3+	2.5	3.2
	EB	Tassjara	Vasco	2	2+	0.0	0.0
	EB	Vasco	San Joaquin County Line	1	3+	2.5	3.2
CA 237	WB	I-880	CA 85	1	3+	15.0	18.9
	EB	CA 85	I-880	1	3+	1.0	1.3

CA 87	NB	CA 85	US 101	1	3+	2.0	2.5
	SB	CA 85	US 101	1	3+	1.0	1.3
I-280	WB	US 101	CA 85	1	3+	1.0	1.3
	EB	CA 85	US 101	1	3+	0.5	0.6

TRANSIT FARES

The forecast year transit networks pivot off a year 2010 baseline network, i.e. the alternatives begin with 2010 conditions and add/remove service to represent the various alternatives. The transit fares in 2010 are assumed to remain constant (in real terms) in all of the forecast years. We are, therefore, explicitly assuming that 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 10 includes fare prices in year 2010 expressed in both year 2000 and year 2010 dollars (i.e., the table does *not* include information about the cost of taking transit in the year 2000).

The above transit fares hold across forecast years for the No Project, Proposed Plan, Transit Priority, and Enhanced Network of Communities alternatives. The Environment, Equity, and Jobs alternative allows travelers under 18 years to travel on transit for free. The intent of the alternative is to allow only low income travelers to use transit for free. Due to time and software limitations, the simulation assumes *all* travelers under 18, even those from households with higher incomes, travel on transit for free.

TABLE 10: YEAR 2010 COMMON TRANSIT FARES†

Operator	*Base fare*	
	$2000	*$2010*
San Francisco Municipal Transportation Agency (Muni)	$1.61	$2.00
Alameda/Contra Costa Transit (AC Transit) – Local buses	$1.61	$2.00
Santa Clara Valley Transportation Authority (VTA) – Local buses	$1.61	$2.00
Santa Clara Valley Transportation Authority (VTA) – Express buses	$4.02	$5.00
San Mateo County Transit (SamTrans) – Local buses	$1.61	$2.00
Golden Gate Transit – Marin County to San Francisco service	$2.93	$3.65
County Connection (CCCTA)	$1.61	$2.00
Vallejo Transit	$1.41	$1.75
Tri-Delta Transit	$1.41	$1.75
Livermore Amador Valley Transit Authority (Wheels, LAVTA)	$1.61	$2.00

† This is a sample, rather than an exhaustive list, of Bay Area transit providers and fares.

PARKING PRICING

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.

In forecasting, we assume that parking prices change over time per a simple model: parking cost is assumed to increase linearly with employment density. Across the alternatives and scenario years, therefore, the parking charges vary with employment density.

PERCEIVED AUTOMOBILE OPERATING COST AND VEHICLE-MILES TRAVELED TAX

When deciding between traveling in a private automobile or on a transit vehicle (or by walking, bicycling, etc.), MTC 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.

In an effort to improve consistency among travel models across the state, the Regional Targets Advisory Committee (formed in response to 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. Using forecasts generated by the United States Department of Energy (DOE) in the Summer of 2010 (and expressed in year 2009 dollars), MPOs agreed to use the fuel prices and non-fuel-related prices presented in Table 10, which is a weighted average of DOE's low-end estimate (25 percent weight) and DOE's high-end estimate (75 percent), plus a 25 cents surcharge to account for fuel generally being more expensive in California. The average fleet-wide fuel economy implied by the EMFAC software – also presented in Table 11 – is used to represent the average fleet-wide fuel economy.

TABLE 11: PERCEIVED AUTOMOBILE OPERATING COST CALCULATIONS

Measure	*Analysis year*			
	2010	*2020*	*2035*	*2040*
Average fuel price (Year 2000 dollars per gallon)	$2.61	$3.81	$4.21	$4.33
Average fuel price (Year 2009 dollars per gallon)	$3.25	$4.74	$5.24	$5.40
EMFAC-implied fuel economy (miles per gallon)	21.35	24.10	30.88	31.26
Non-fuel-related operating cost ($2000 per mile)	$0.06	$0.07	$0.09	$0.09
Non-fuel-related operating cost ($2009 per mile)	$0.08	$0.09	$0.11	$0.12
Perceived automobile operating cost ($2000 per mile)[†]	$0.18	$0.22	$0.22	$0.23
Perceived automobile operating cost ($2009 per mile)[†]	$0.23	$0.28	$0.28	$0.29

[†] Sum of the fuel-related operating cost (average fuel price divided by average fuel economy) and non-fuel-related operating cost

With one exception, the assumptions shown in Table 10 hold across each of the forecast year alternatives. Specifically, the year 2020, 2035, and 2040 simulations for the No Project, Proposed Plan, Transit Priority, and Enhanced Network of Communities use the perceived automobile operating costs shown in Table 10.

The Environment, Equity, and Jobs alternative increases the perceived automobile operating costs by 1 cent per mile ($2011; 0.78 cents per mile in year 2000 dollars) in each of the forecast year alternatives. This additional penny per mile is intended to simulate a vehicle-miles traveled tax. Per the vision of the crafters of this alternative, low income travelers would be exempt from the tax. Due to time and software limitations, the simulation assumes *all* travelers, even low income travelers, pay the tax.

CORDON TOLLS

The Proposed Plan, Transit Priority, Enhanced Network of Communities, and Environment, Equity, and Jobs alternatives include a cordon toll in San Francisco. The scheme requires all vehicles to pay a $3.00 ($2010; $2.40 in year 2000 dollars) fee to enter the greater downtown San Francisco area during the morning and evening commute periods. The cordoned area is bounded by Laguna Street to the West, 18th Street to the South, and the San Francisco Bay to the North and East[13].

Other Key Assumptions

An additional key assumption relates to telecommuting. Technology is currently allowing large numbers of Bay Area residents to work at home[14] and the MTC travel model allows for the explicit representation of full-time workers staying home on the typical weekday simulation. In the forecast years, MTC assumes the trend of workers working at home revealed in the 1980, 1990, 2000, and 2010 Census will continue through 2040. Figure 9 presents the historical data, the trend, and the MTC forecasts. These telecommuting assumptions are the same across alternatives, meaning full-time workers telecommute at the same rate in the No Project, Proposed Plan, Transit Priority, Enhanced Network of Communities, and Environment, Equity, and Jobs alternatives.

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13 Additional details are available from San Francisco County here: http://www.sfcta.org/content/view/468/288/.

14 Additional information is available here: http://www.workshifting.com/downloads/downloads/Telework-Trends-US.pdf.

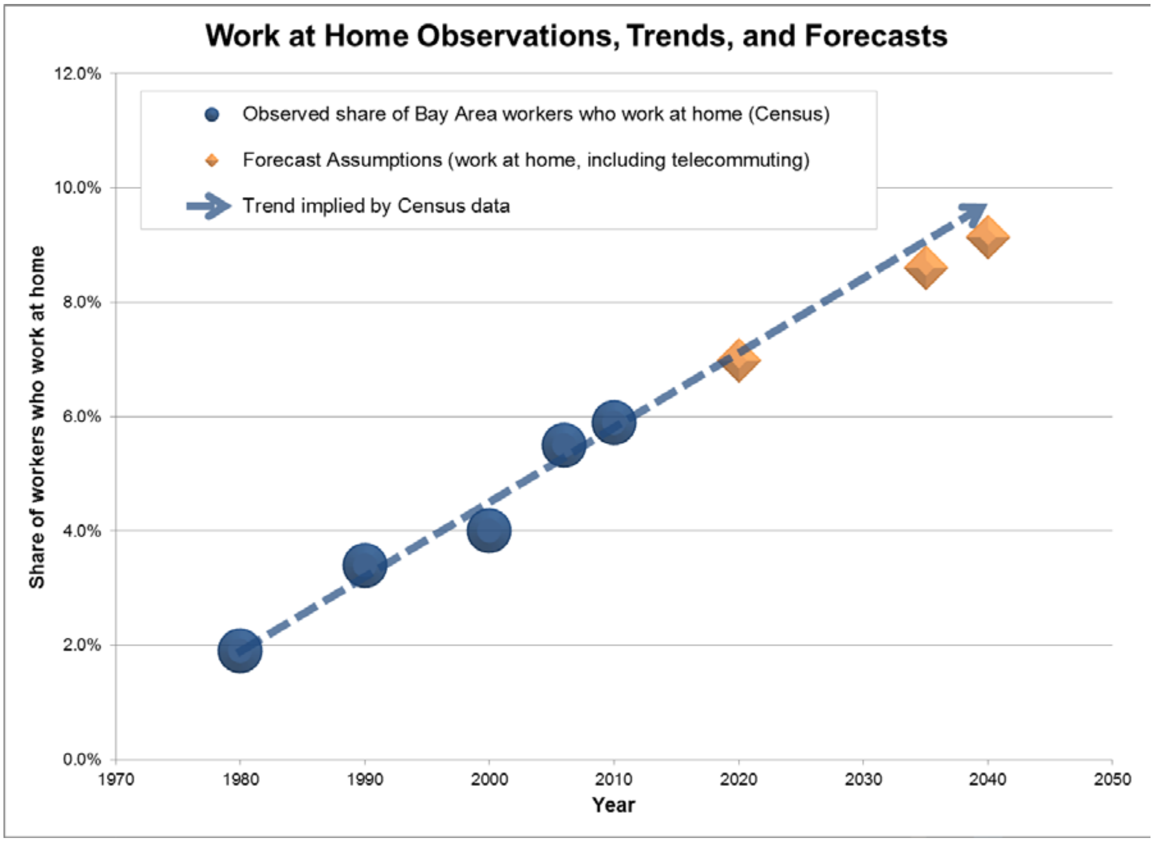


FIGURE 9: WORK AT HOME OBSERVATIONS, TRENDS, AND FORECASTS

4 Key Results

Selected travel model results across a variety of dimensions are summarized and discussed here. The presented results are not exhaustive and are intended only to give the reader a general sense of the expected behavioral changes in response to differing input assumptions across the alternatives and forecast years.

Performance Targets and Equity Analysis

The purpose of this document is to describe the response of travelers to the projects and policies implemented in the alternatives described in the previous section. Information from the travel model is also used to help assess the performance of each of the alternatives per agency-adopted targets. This information is described in the *Performance Assessment Report* available at www.onebayarea.org.

Information from the travel model is also used to analyze how different populations are impacted by the investments and policies included in each alternative. This information is described in the *Equity Analysis Report* available at www.onebayarea.org.

Automobile Ownership

Figure 10 presents the automobile ownership rates across the five alternatives in the year 2040 simulations as well as year 2010. The differences across alternatives are not dramatic. One key finding is the general increase in zero automobile households in the Proposed Plan, Transit Priority, Enhanced, and EEJ alternatives.

To give a sense of the change in automobile ownership over time, results for the Proposed Plan alternative simulations for 2020, 2030, and 2040 are compared to year 2010 results in Figure 11. Here, we see a steady increase in zero automobile households and a steady decrease in two automobile households.

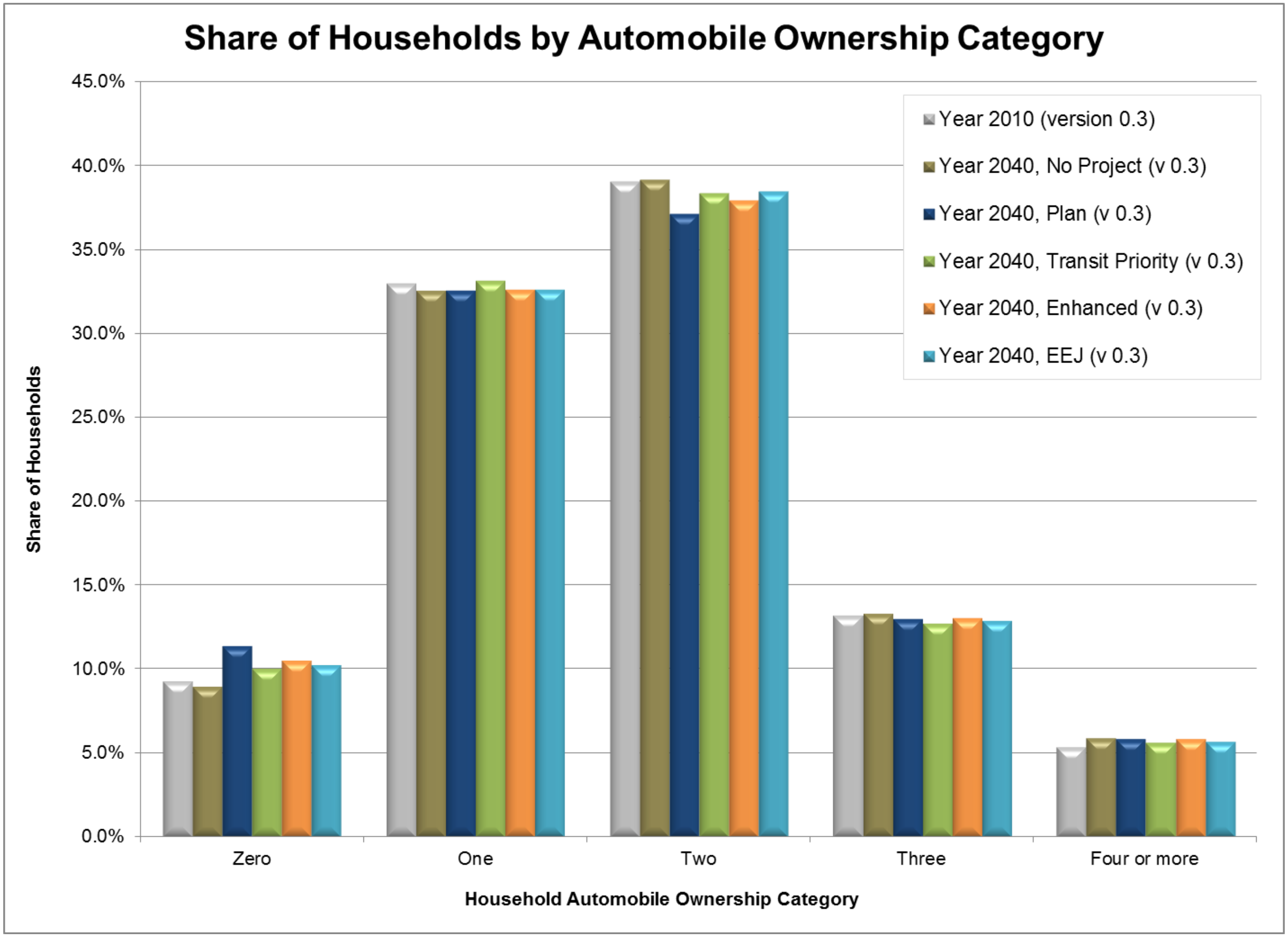


FIGURE 10: YEAR 2040 AUTOMOBILE OWNERSHIP RESULTS

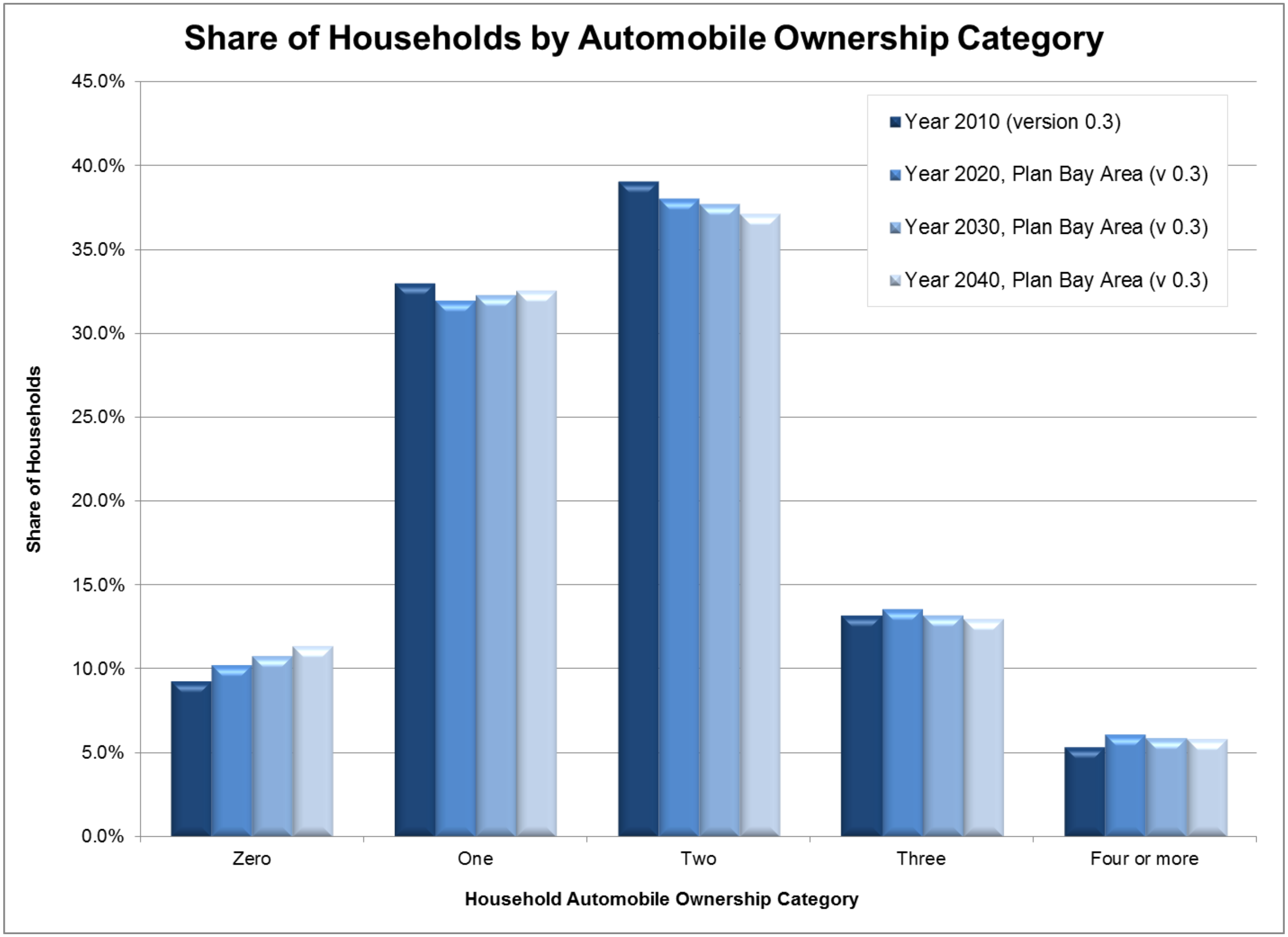


FIGURE 11: AUTOMOBILE OWNERSHIP RESULTS FOR PROPOSED PLAN ALTERNATIVE

Activity Location Decisions

Figure 12 and Figure 14 present the average trip distance by travel mode for all travel and for trips on work tours, respectively, for the year 2010 and the year 2040 alternatives. The key finding here is that each of the five forecast alternatives brings activities closer together relative to 2010. The substantial investment in transit technologies that tend to serve longer distance travel markets, such as commuter rail (see Figure 6), causes the average transit trip distance to increase a bit relative to 2010. These trends are more apparent in the summary of work travel in Figure 14.

Companion results for the Proposed Plan alternative for 2020, 2030, and 2040 are presented in Figure 13 and Figure 15. Again, over time, activities are getting closer together and transit is becoming more competitive for longer distance travel. Figure 16 speaks to the volume of travel, showing the change in the Proposed Plan alternative 2020, 2030, and 2040 simulations relative to year 2010. As the population increases, so does the amount of travel.

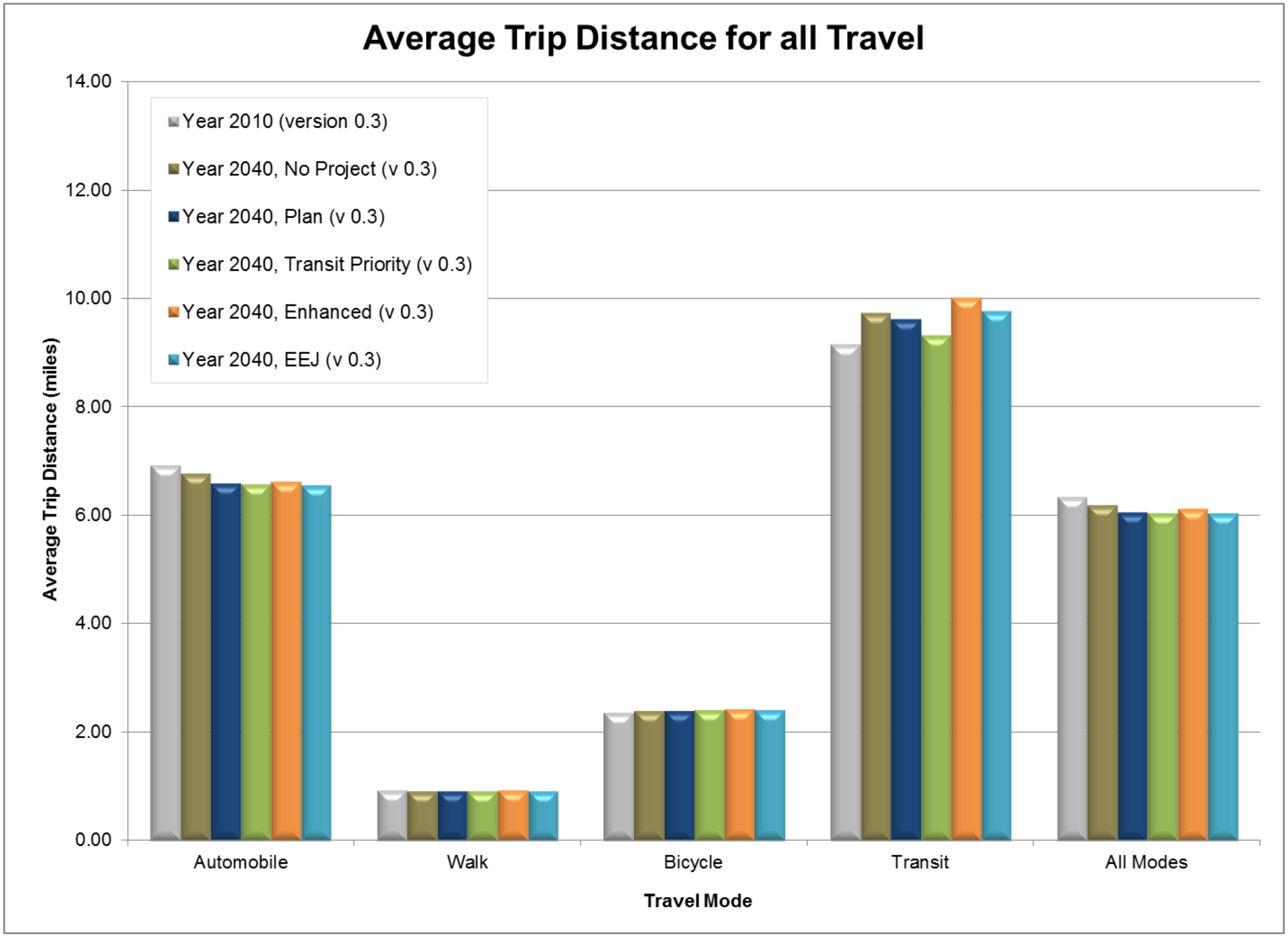


FIGURE 12: YEAR 2040 AVERAGE TRIP DISTANCE

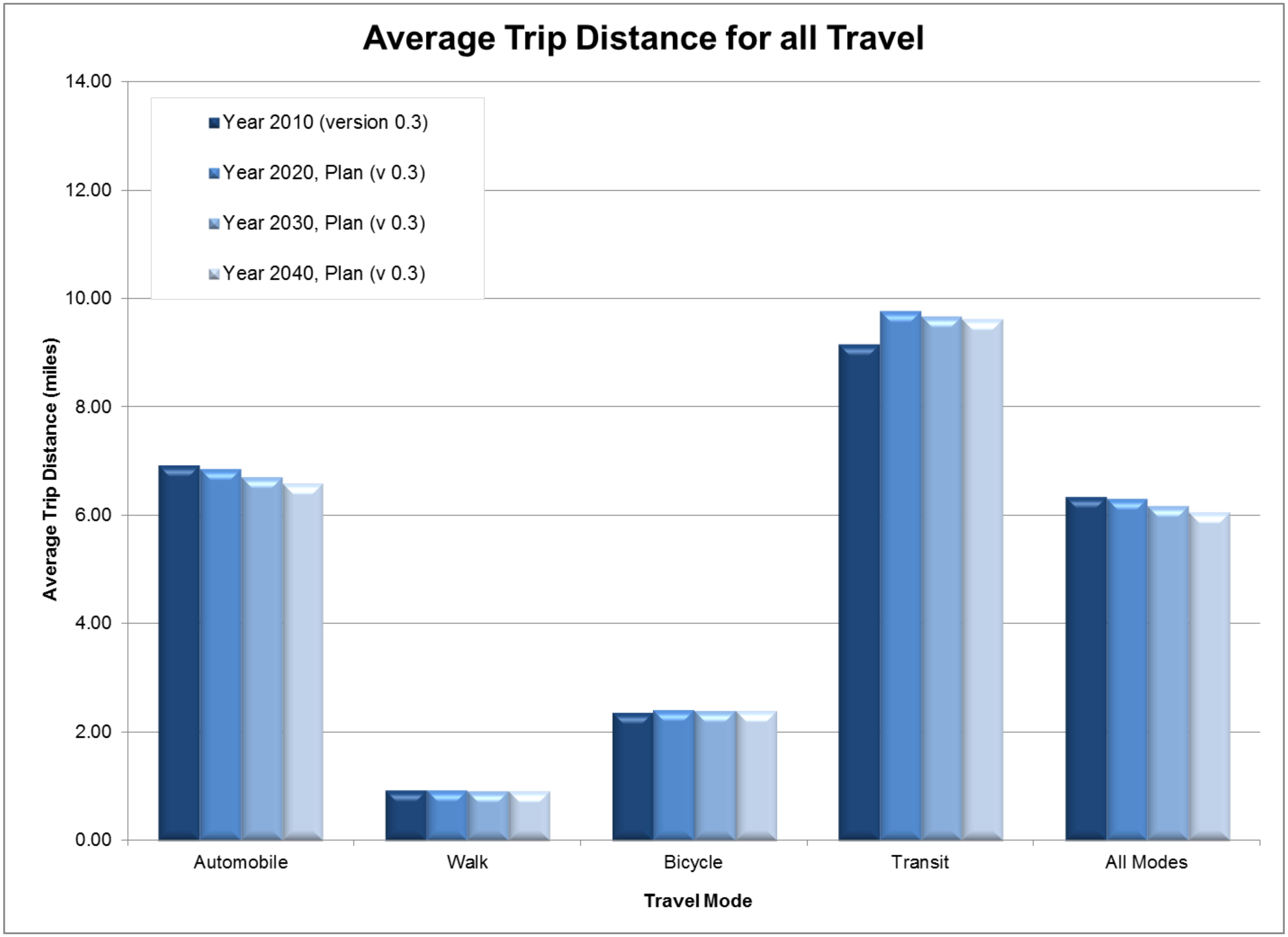


FIGURE 13: AVERAGE TRIP DISTANCE FOR PROPOSED PLAN ALTERNATIVE

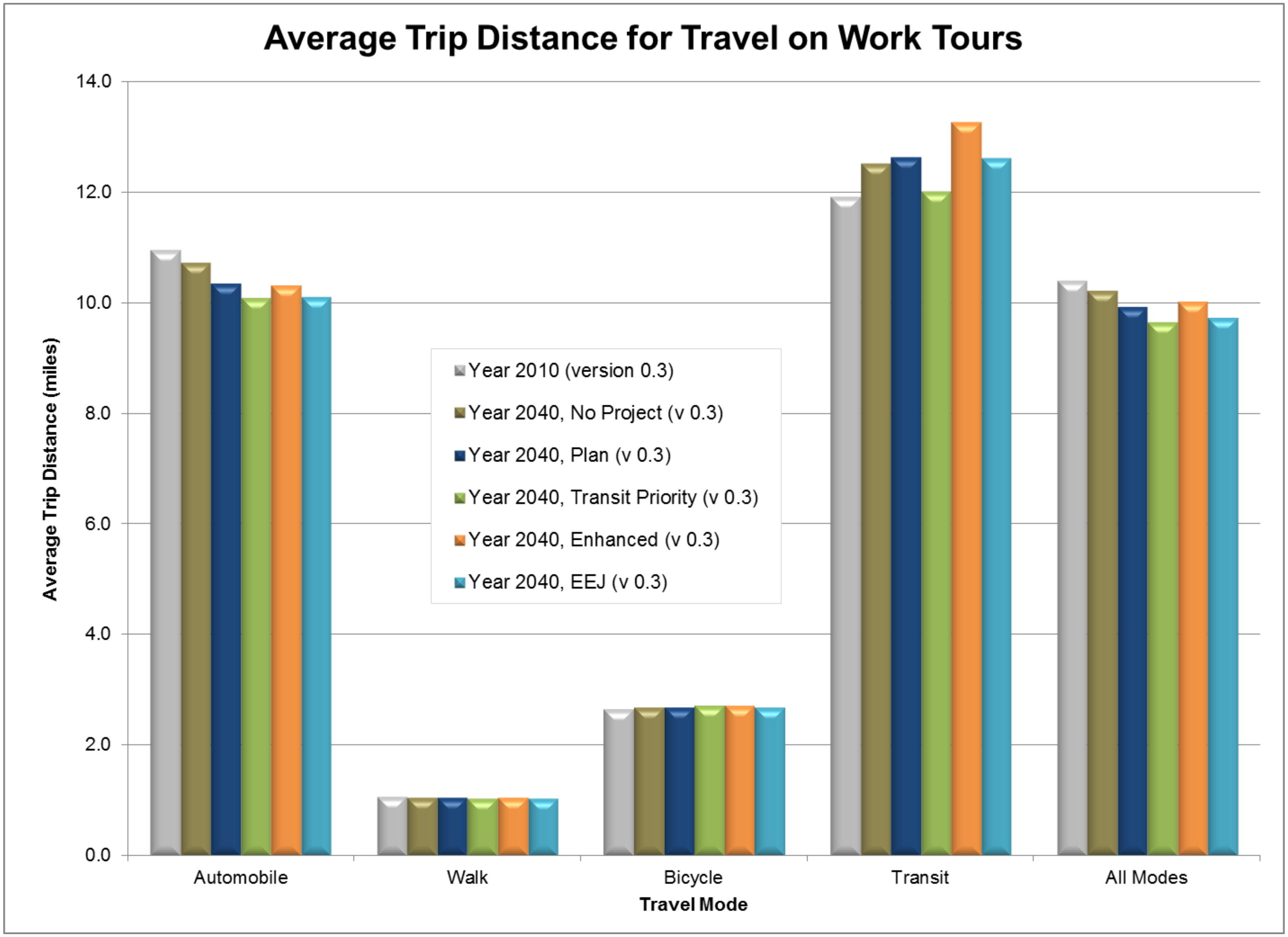


FIGURE 14: YEAR 2040 AVERAGE TRIP DISTANCE FOR TRAVEL ON WORK TOURS

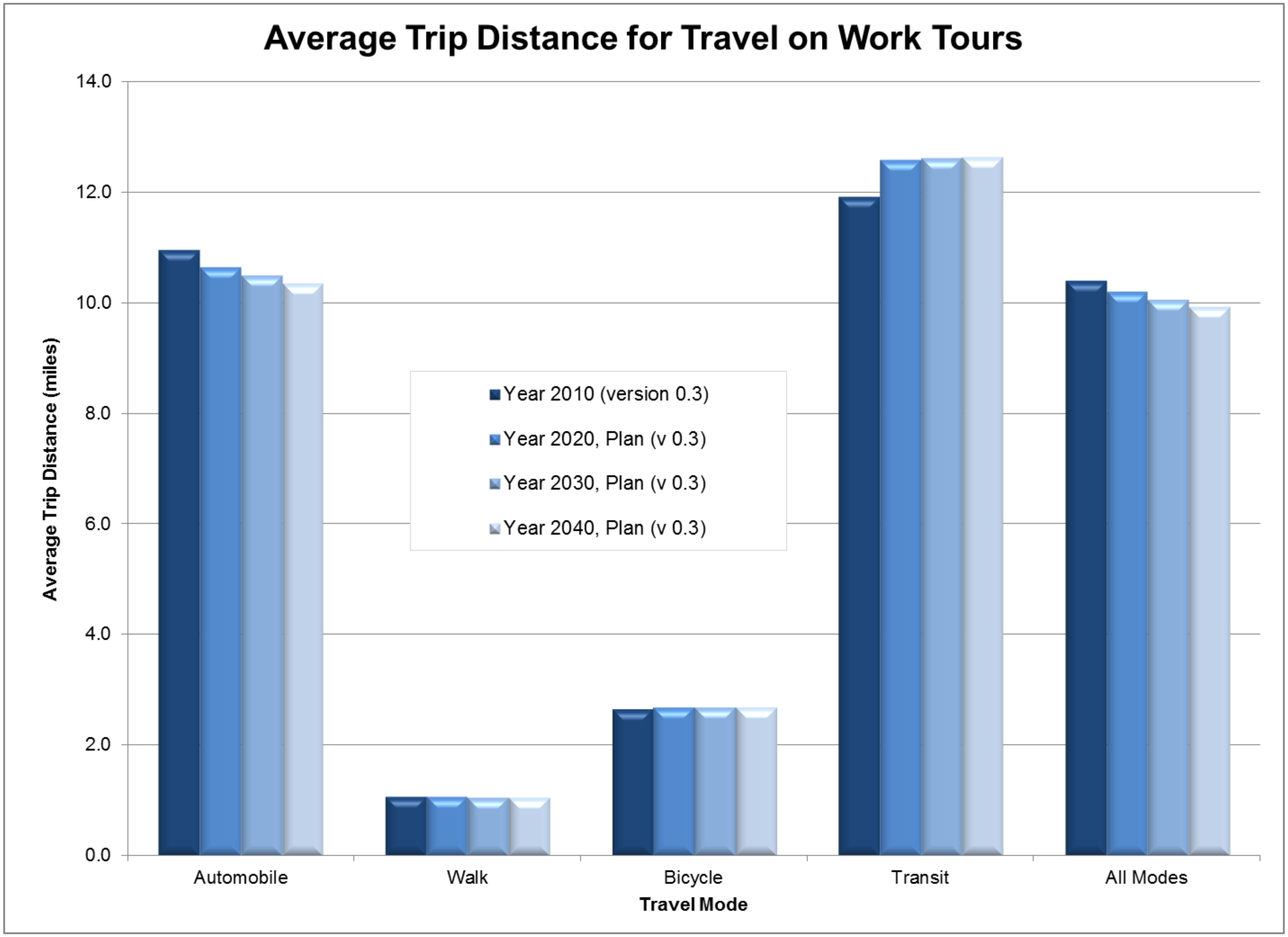


FIGURE 15: AVERAGE TRIP DISTANCE FOR TRAVEL ON WORK TOURS FOR PROPOSED PLAN ALTERNATIVE

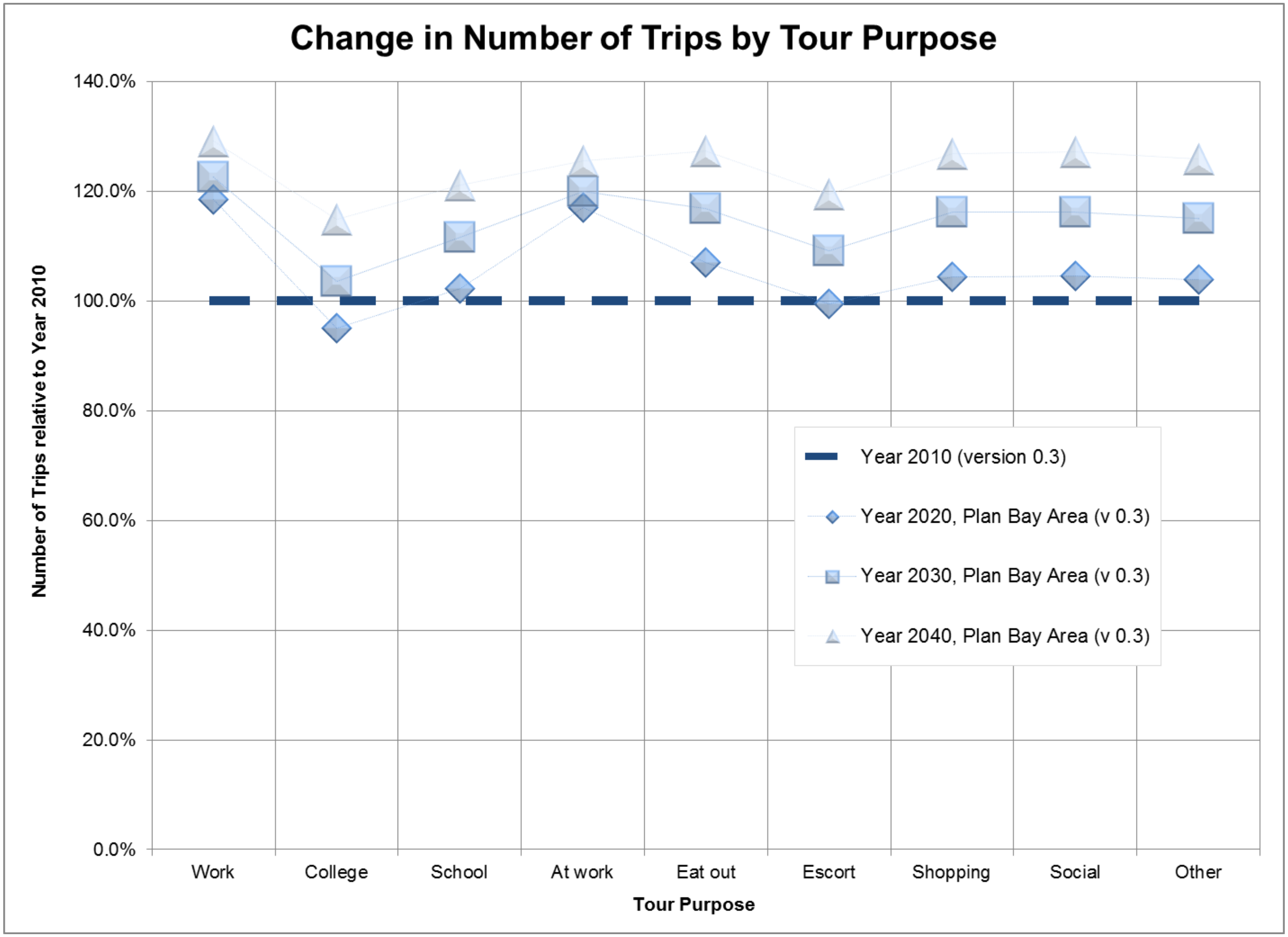


FIGURE 16: CHANGE IN NUMBER OF TRIPS BY TOUR PURPOSE FOR PROPOSED PLAN ALTERNATIVE

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, five automobile-based modal options are considered, specifically:

- traveling alone in a private automobile and opting *not* to pay to use an express lane ("single occupant, no HOT"), an option only available to those in households who own at least one automobile;
- traveling alone in a private automobile and opting to pay to use an express lane ("single occupant, pay to use HOT"), an option only available to those who both own a car and whose journey would benefit from using the express lane facility (e.g., this option is not available to those driving through a residential neighborhood to drop a child at school);
- traveling with one other occupant in a private automobile and opting *not* to pay to use an express lane ("two occupants, no HOT") (these travelers can use carpool lanes for which they are eligible), an option available to those in households with and without automobiles;
- traveling with one other occupant in a private automobile and opting to pay to use an express lane ("two occupants, pay to use HOT"), an option available to those in households with and without automobiles but only to those who would benefit from using an express lane (if the express lane facility which benefits these travelers allows two occupant vehicles to travel for free, than these travelers are categorized as "two occupants, no HOT"); and,
- traveling with two other occupants in a private automobile ("three-or-more occupants") – these vehicles are uniformly allowed to travel for free on express lane facilities across all of the alternatives (as well as carpool facilities).

The travel model explicitly considers numerous non-automobile options which are collapsed here 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 17 and Figure 18 present the share of trips made by various travel modes. Figure 17 shows shares of travel in automobile by occupancy category as well as willingness to pay to use an express lane. Overall, we predict Bay Area residents will reduce the share of travel accomplished in a private automobile from about 83 percent in 2010 to just below 80 percent in 2040 in the Proposed Plan, Transit Priority, and Environment, Equity, and Jobs alternatives. Figure 18 presents companion results for non-automobile travel models, including public transit, walking, and bicycling. Here, we see an increase in walking and transit across the year 2040 alternatives, which reflect the increases in transit service and increasingly efficient land development patterns.

Figure 19 and Figure 20 show the automobile and non-automobile travel mode share results for the year 2020, 2030, and 2040 simulations of the Proposed Plan alternative. Here, we see a steady but small shift to non-automobile modes from 2010 to 2040.

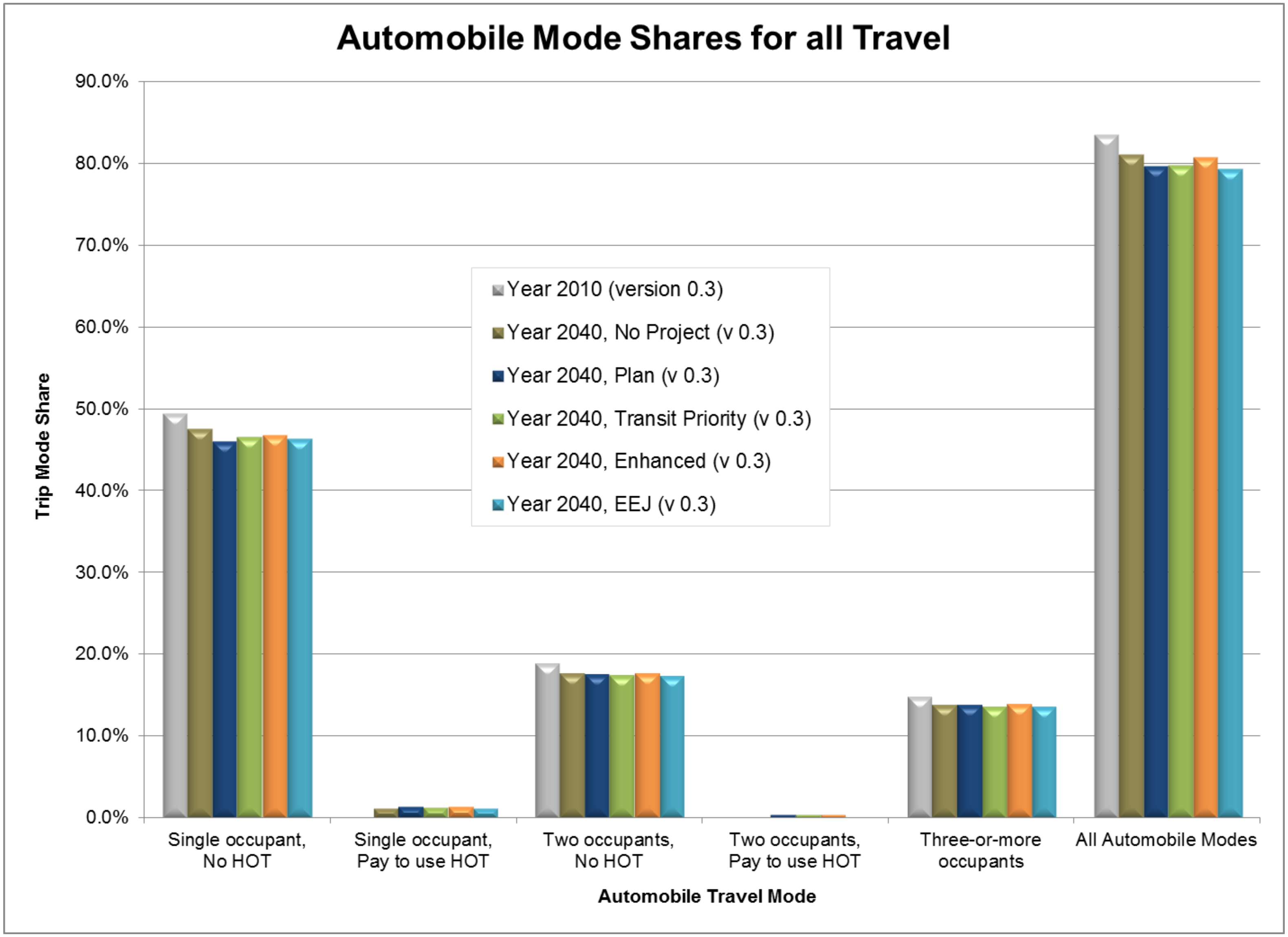


FIGURE 17: YEAR 2040 AUTOMOBILE MODE SHARES FOR ALL TRAVEL

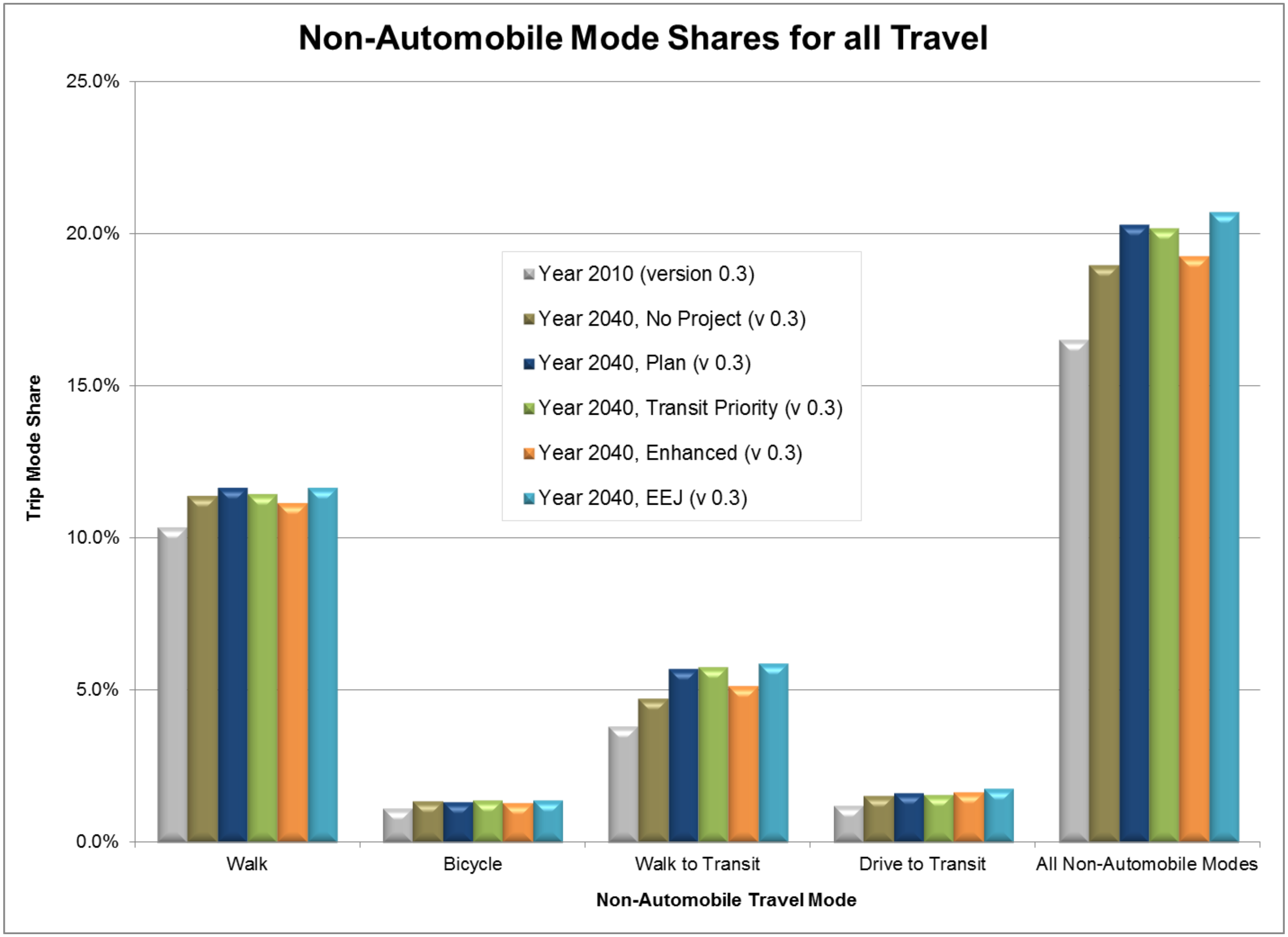


FIGURE 18: YEAR 2040 NON-AUTOMOBILE MODE SHARES FOR ALL TRAVEL

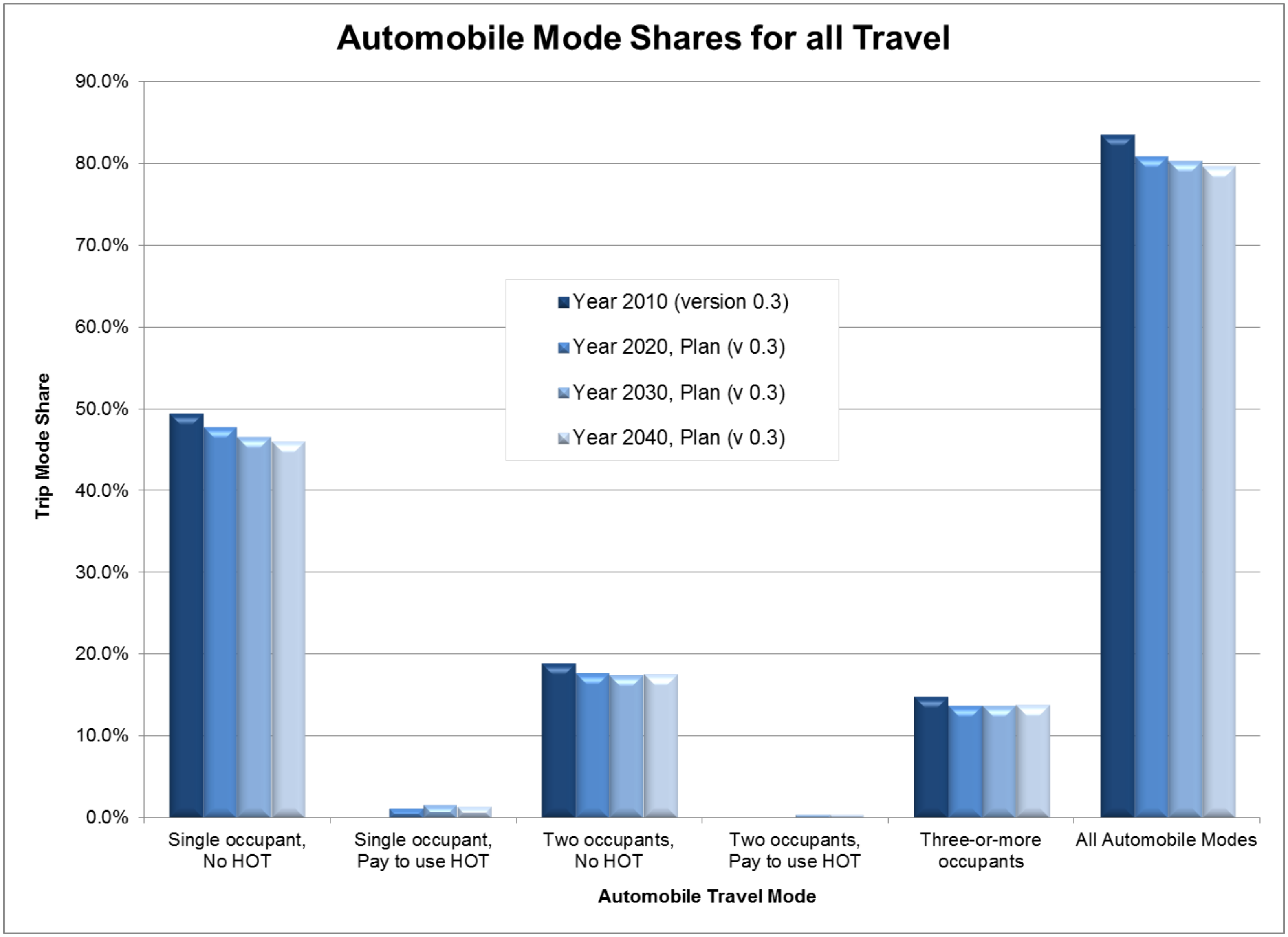


FIGURE 19: AUTOMOBILE MODE SHARES FOR ALL TRAVEL FOR PROPOSED PLAN ALTERNATIVE

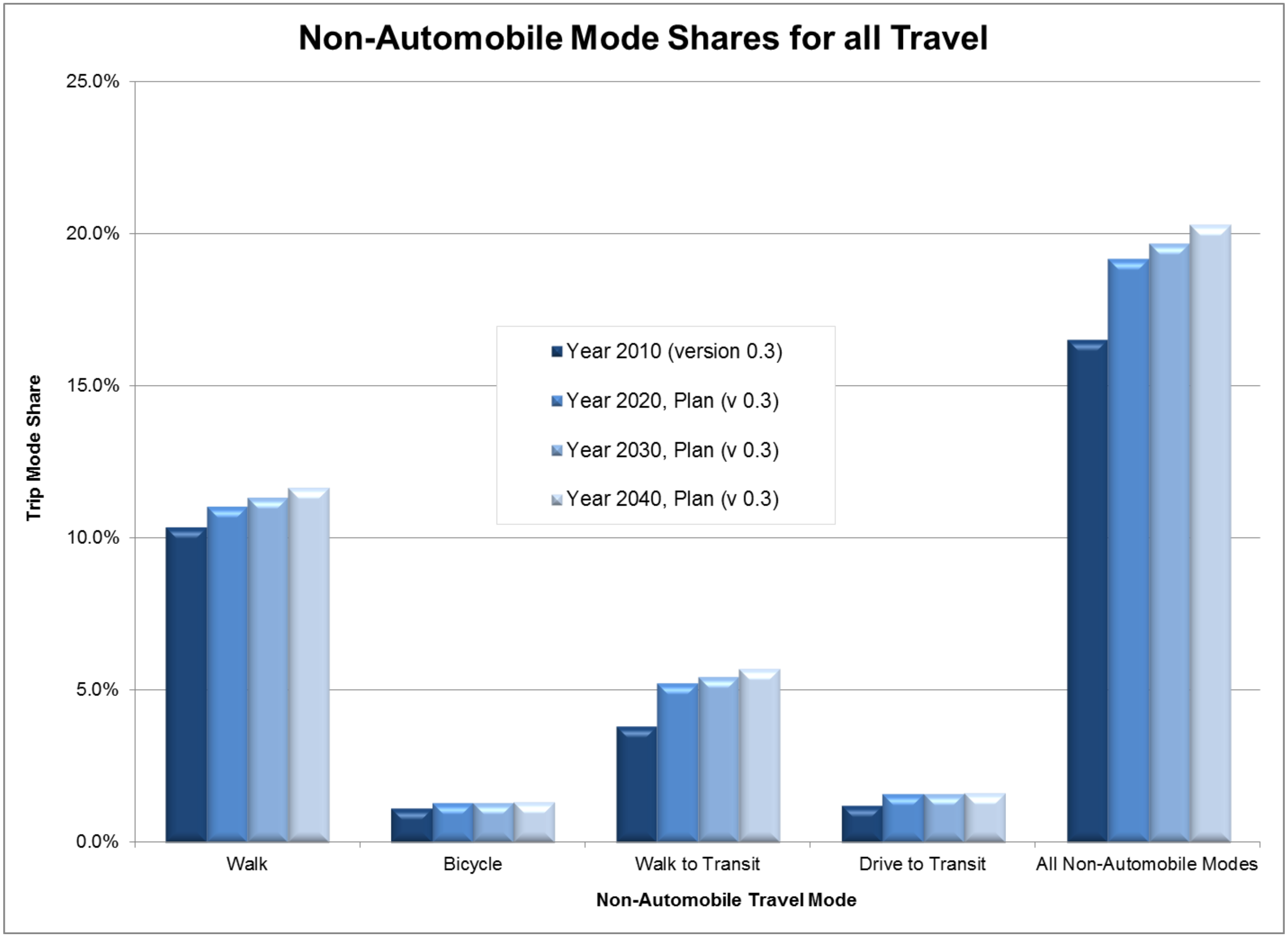


FIGURE 20: NON-AUTOMOBILE MODE SHARES FOR ALL TRAVEL FOR PROPOSED PLAN ALTERNATIVE

Aggregate Transit Demand Estimates

Bay Area residents choosing to travel by transit are explicitly assigned to a specific transit service. As a simplification, MTC groups transit lines into the following technology-specific categories:

- **Local bus**: standard, fixed-route bus service, of the kind a traveler may take to and from a neighborhood grocery store, as well as so-called "bus rapid transit" service.
- **Express bus**: longer distance service typically provided in over-the-road coach technology. Golden Gate Transit, for example, provides express bus service between Marin County and Downtown San Francisco.
- **Light rail**: represented in the Bay Area by San Francisco's Muni Metro and F-Market streetcar services, as well as Santa Clara Valley Transportation Authority's light rail service.
- **Heavy rail**: another name for the Bay Area Rapid Transit (BART) service.
- **Commuter rail**: longer distance rail service typically provided on grade-separated railroads, including Caltrain, SMART, Capitol Corridor, Altamont Commuter Express, and Amtrak.

Figure 21 presents the estimates of transit boardings by these categories on the typical weekday simulated by the travel model. The Environment, Equity, and Jobs alternative, which includes the most expansive transit system across the five alternatives (see the Transit Supply section), has the highest expected transit ridership at about 3.2 million daily boardings, which is approximately twice the year 2010 estimate of 1.6 million boardings.

Figure 22 shows boardings for year 2010 as well as the year 2020, 2030, and 2040 Proposed Plan alternative simulations. Here, a steady and substantial increase in ridership is expected every decade.

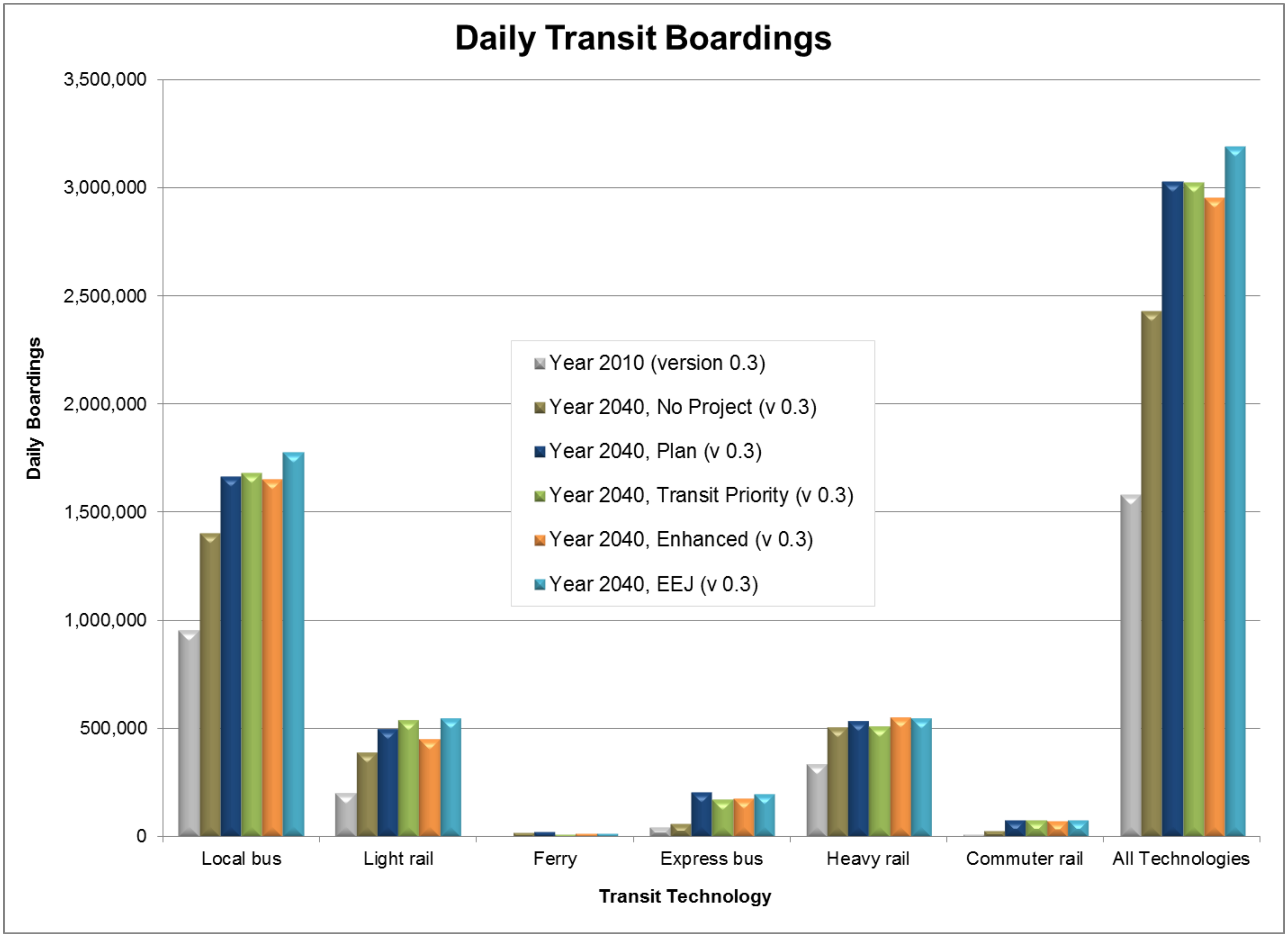


FIGURE 21: YEAR 2040 TYPICAL WEEKDAY TRANSIT BOARDINGS BY TECHNOLOGY

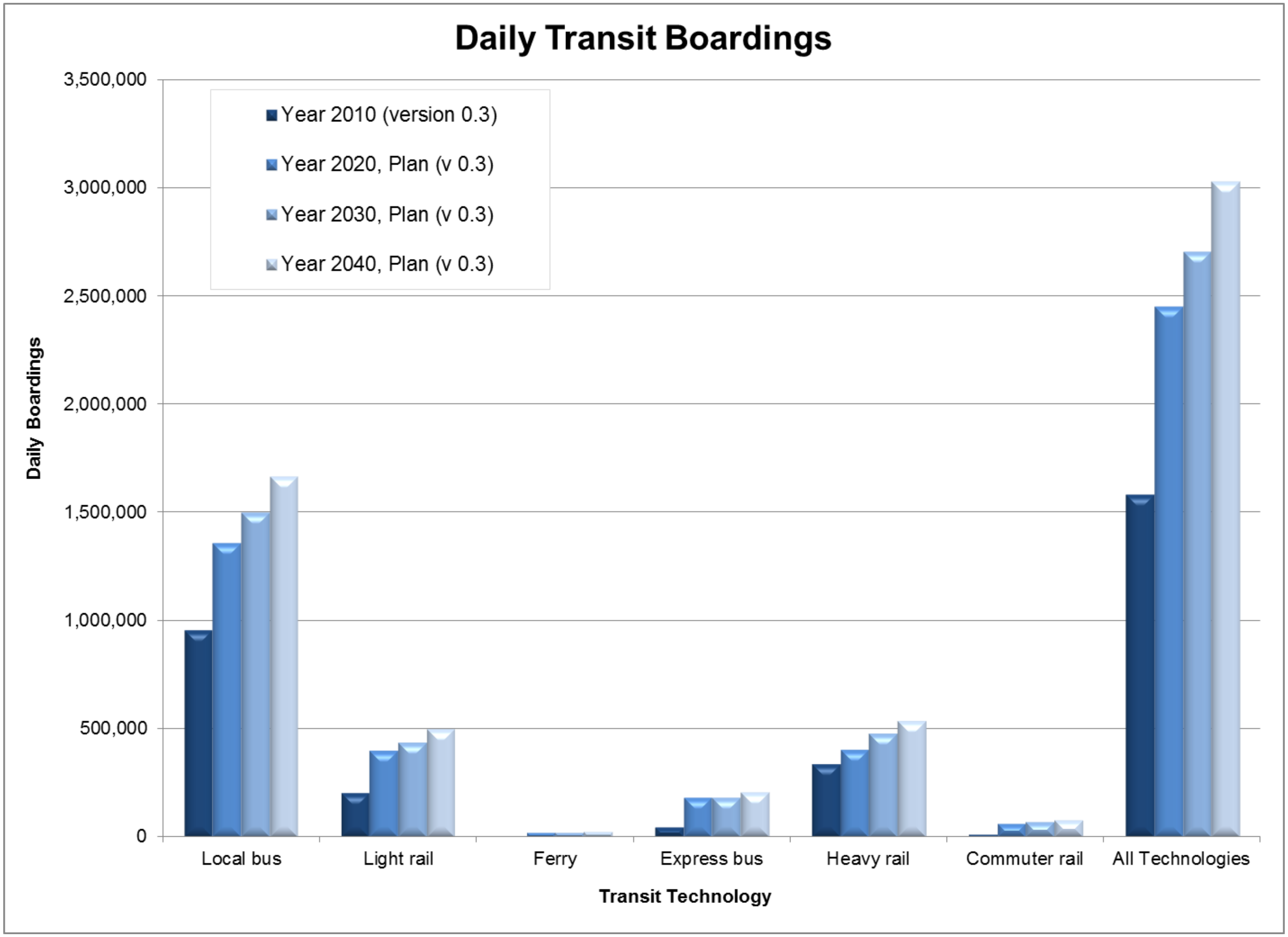


FIGURE 22: TYPICAL WEEKDAY BOARDINGS BY TECHNOLOGY FOR PROPOSED PLAN ALTERNATIVE

Roadway 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 is expressed in monetary and non-monetary (e.g., time) units). The assignment process inherently computes numerous quantities of interest, such as vehicle miles traveled, delay, and average travel speed.

Please note that MTC maintains three separate estimates of the quantity of vehicle miles traveled (VMT), as follows: (1) the quantity assigned directly to the highway network; (2) the quantity assigned to the highway network plus so-called intra-zonal VMT, which is computed off-line; (3), the quantity (2) adjusted to match the amount of VMT the Air Resources Board (CARB) believes takes place in the Bay Area (a number slightly higher than MTC's estimate). In this document, the VMT identified as quantity (1) in the above list is presented; the emission estimates (presented in the next subsection) are based on the VMT identified as quantity (3).

Figure 23 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 2010 to 2040. Overall, VMT varies only slightly across the year 2040 alternatives, with the Enhanced Network of Communities alternative having the highest VMT due to the larger Bay Area population assumed in this alternative.

Figure 24 presents the average freeway speed across the alternatives. Looking at the speeds during the morning and evening commute periods, we see a reduction in speed (or, said another way, an increase in congestion) from the year 2010 scenario to the year 2040 No Project alternative. Each of the alternatives improves freeway speed, with the greatest improvement coming in the Transit Priority alternative.

Figure 25 and Figure 26 present hourly VMT and freeway speeds for the year 2020, 2030, and 2040 simulations of the Proposed Plan alternative. In these charts, we can see VMT growing over time and freeway speeds degrading after 2020.

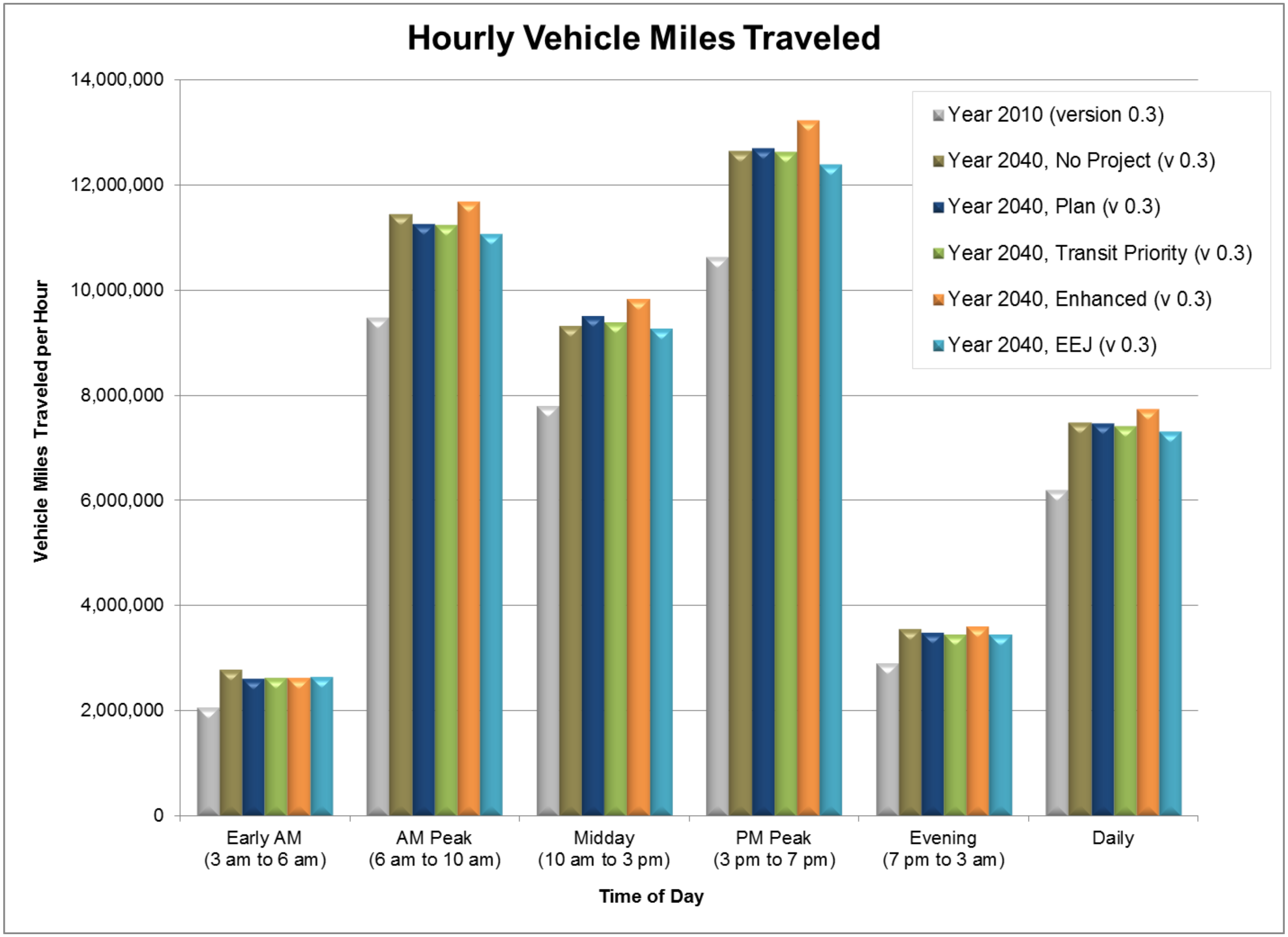


FIGURE 23: YEAR 2040 VEHICLE MILES TRAVELED PER HOUR BY TIME PERIOD

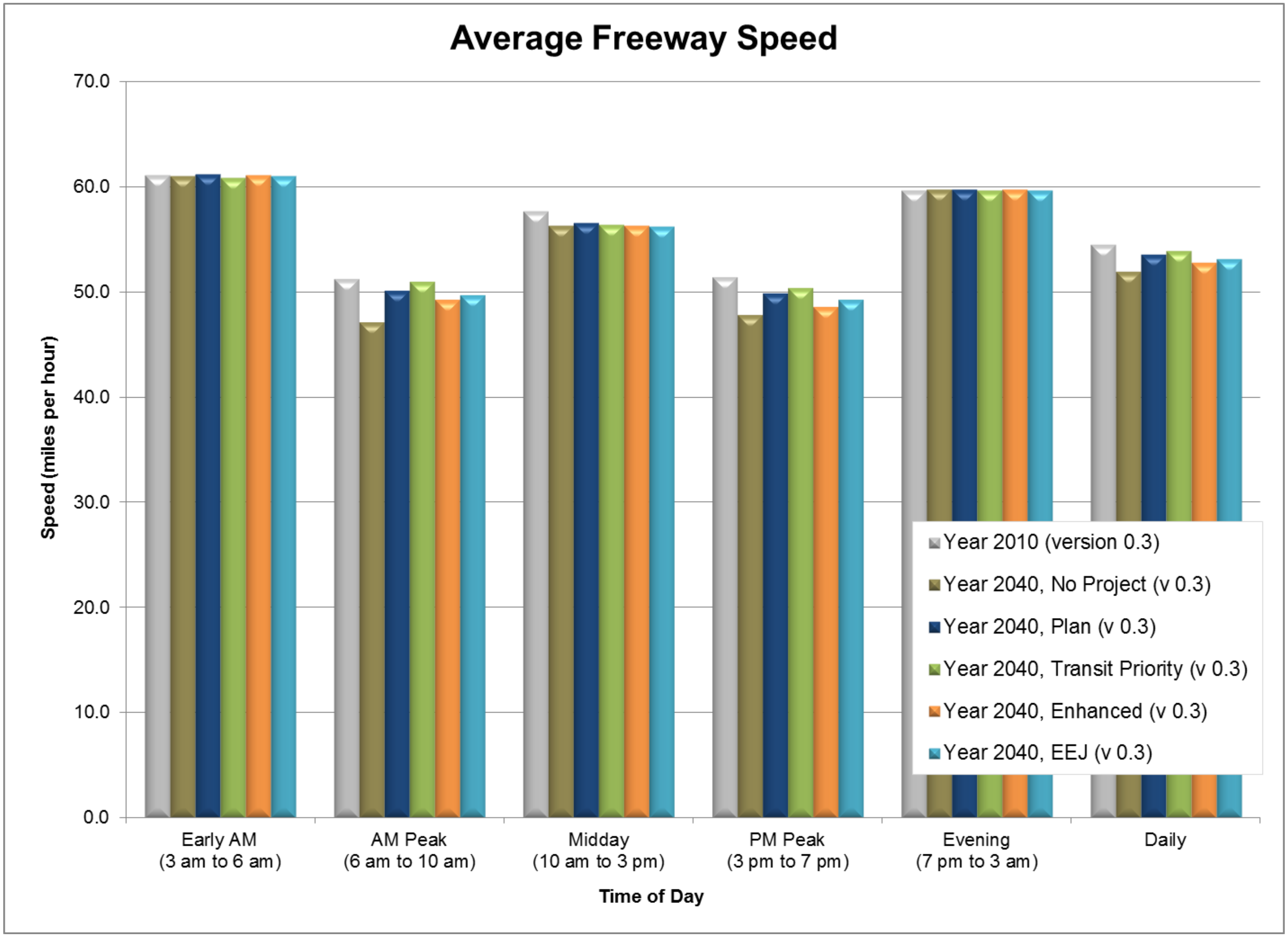


FIGURE 24: YEAR 2040 AVERAGE VEHICLE SPEEDS ON FREEWAYS

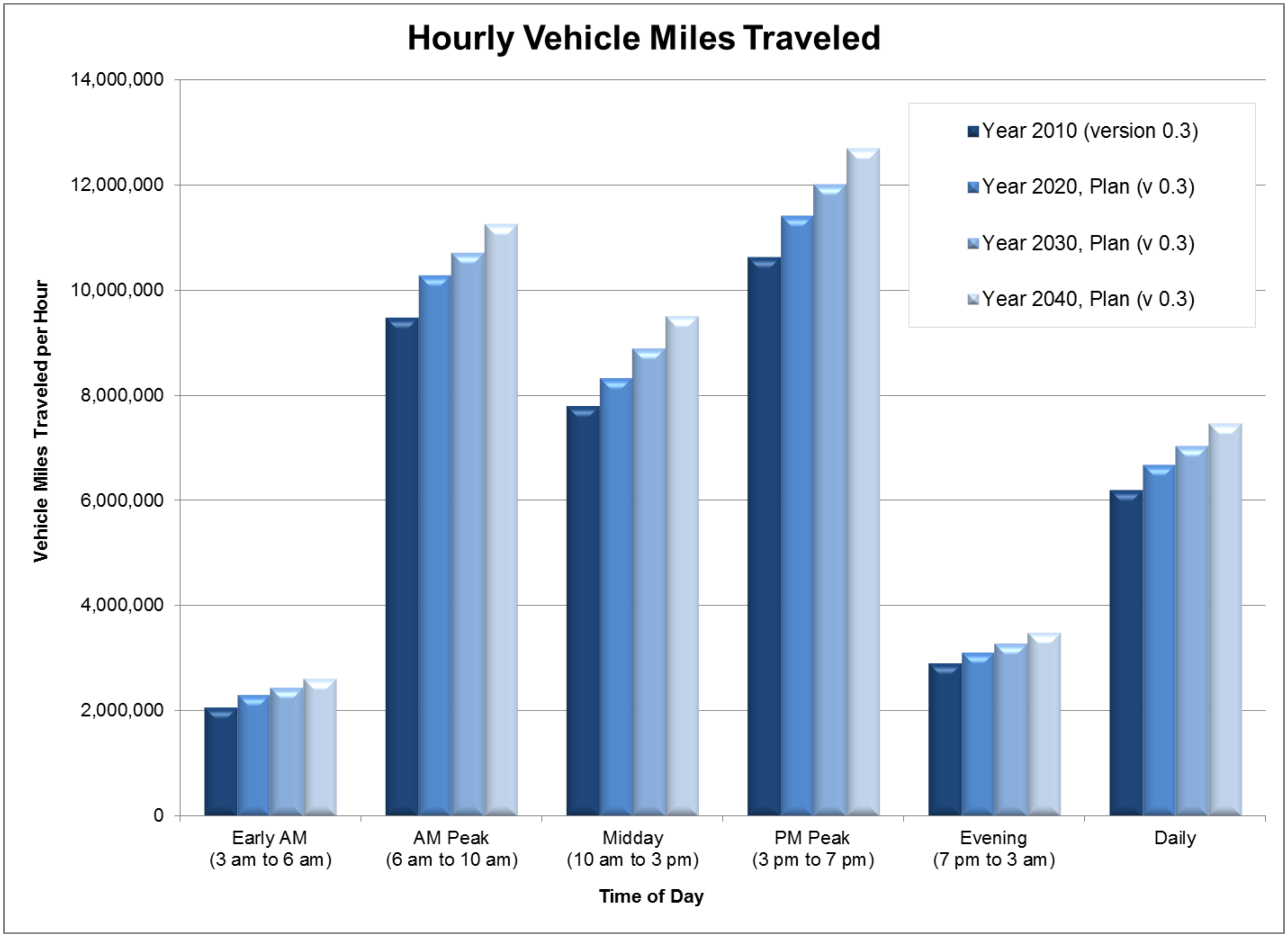


FIGURE 25: VEHICLE MILES TRAVELED PER HOUR FOR PROPOSED PLAN ALTERNATIVE

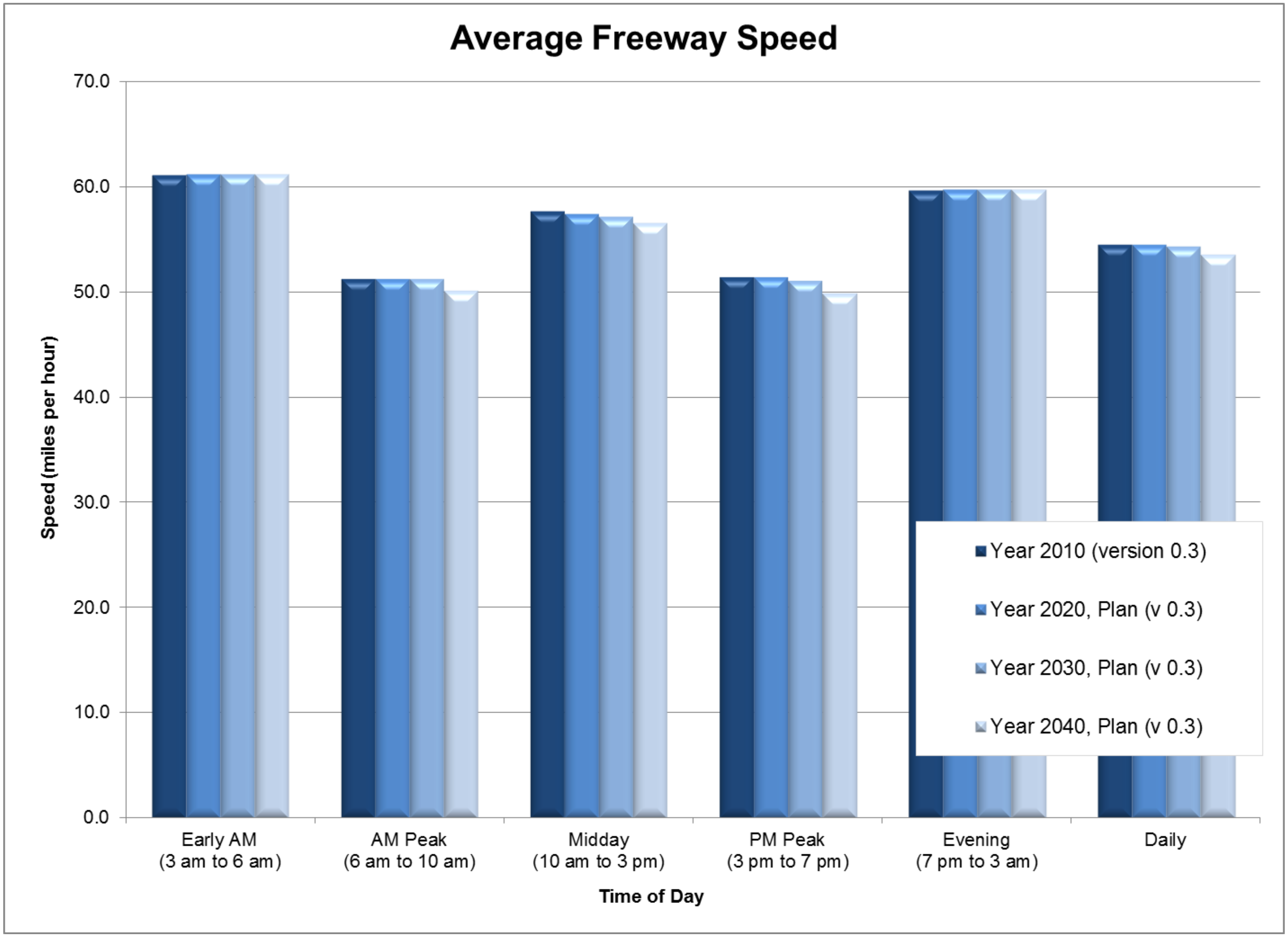


FIGURE 26: AVERAGE VEHICLE SPEEDS ON FREEWAYS FOR PROPOSED PLAN ALTERNATIVE

Air Quality Implications

Table 12 and Table 13 summarize various on-road mobile source emission estimates across alternatives for Year 2040 and for Years 2010, 2020, 2030, and 2040 for the Proposed Plan alternative. A few key notes on these tables are as follows:

- Carbon dioxide, which serves as a proxy for all greenhouse gas emissions, is reported for the nine county Bay Area (rather than the MTC air basin);
- All other pollutants are reported for the MTC air basin, which includes portions of Solano and Sonoma Counties;
- Carbon dioxide is reported two ways: the first ignores vehicle and fuel regulations (specifically the so-called Pavley[15] regulations and low-carbon fuel standard) and the second considers the impact of vehicle and fuel regulations; and,
- Pollutants subject to vehicle control regulations decrease, in some cases dramatically, when moving from the current year through the forecast years.

[15] Additional information is available here: http://www.arb.ca.gov/cc/ccms/ccms.htm.

TABLE 12: YEAR 2040 ON-ROAD MOBILE SOURCE EMISSION ESTIMATES FOR THE MTC AIR BASIN

	Tons per typical weekday for all vehicles (unless otherwise noted)							
Alternative	*Carbon Dioxide (CO_2)†*	*CO_2† Pounds per Capita*	*Carbon Dioxide (CO_2)††*	*Small Particulate Matter ($PM_{2.5}$)*	*Particulate Matter (PM_{10})**	*Winter Nitrous Oxides (NO_x)*	*Reactive Organic Gases*	*Carbon Monoxide (CO)*
Year 2005 (version 0.3)	71,660	20.5	71,660	8.84	14.95	277.7	137.9	1,321.0
Year 2040, No Project (v 0.3)	84,210	19.3	53,770	5.67	12.50	53.95	36.47	268.5
Year 2040, Proposed Plan (v 0.3)	82,550	18.1	52,700	5.64	12.42	53.71	36.52	266.4
Year 2040, Transit Priority (v 0.3)	82,270	18.4	52,520	5.61	12.37	53.31	36.47	265.9
Year 2040, Enhanced (v 0.3)	85,670	18.1	54,690	5.85	12.88	55.59	38.00	277.0
Year 2040, EEJ (v 0.3)	81,410	18.3	51,970	5.55	12.24	52.77	35.80	262.2

† - Passenger vehicle emissions for the nine-county Bay Area, excluding – per SB 375 – expected reductions from fuel and vehicle regulations and excluding reductions from MTC's Climate Initiatives Program;
†† - Passenger vehicle missions for the nine-county Bay Area, including reductions expected from Pavley I and Low Carbon Fuel Standard Regulations and excluding reductions from Climate Initiatives Program;
* - Does not include road dust.

TABLE 13: ON-ROAD MOBILE SOURCE EMISSION ESTIMATES FOR THE MTC AIR BASIN FOR PROPOSED PLAN ALTERNATIVE

	Tons per typical weekday for all vehicles (unless otherwise noted)							
Alternative	*Carbon Dioxide (CO_2)†*	*CO_2† Pounds per Capita*	*Carbon Dioxide (CO_2)††*	*Small Particulate Matter ($PM_{2.5}$)*	*Particulate Matter (PM_{10})**	*Winter Nitrous Oxides (NO_X)*	*Reactive Organic Gases*	*Carbon Monoxide (CO)*
Year 2005 (version 0.3)	71,660	20.5	71,660	8.84	14.95	277.7	137.9	1,321.0
Year 2010 (version 0.3)	70,090	19.0	69,820	6.84	12.63	185.3	93.66	879.9
Year 2020, Proposed Plan (v 0.3)	74,420	19.3	54,350	5.04	11.08	83.22	46.80	374.4
Year 2030, Proposed Plan (v 0.3)	78,010	18.6	50,730	5.30	11.68	55.14	37.53	272.4
Year 2040, Proposed Plan (v 0.3)	82,550	18.1	52,700	5.64	12.42	53.71	36.52	266.4

† - Passenger vehicle emissions for the nine-county Bay Area, excluding – per SB 375 – expected reductions from fuel and vehicle regulations and excluding reductions from MTC's Climate Initiatives Program;
†† - Passenger vehicle missions for the nine-county Bay Area, including reductions expected from Pavley I and Low Carbon Fuel Standard Regulations and excluding reductions from Climate Initiatives Program;
* - Does not include road dust.

5 Off-Model Emission Reduction Estimates

MTC, with consultant assistance from ICF International, prepared "off-model", or "sketch modeling", analyses of various transportation-focused Climate Policy Initiatives anticipated to produce measurable per-capita greenhouse gas (GHG) emission reductions. Investments are made in programs that will accelerate the adoption of clean vehicle technologies, encourage changes in how we drive, and promote alternative travel modes.

Primary inputs into the sketch modeling analyses were outputs from *Travel Model One* in years 2005, 2020, 2035, and 2040, as well as emissions factors from ARB's EMFAC2011.

The Climate Policy Initiatives include:

1. Regional Charger Program for Plug-In Hybrid Electric Vehicles
2. Vehicle Buy-Back and Plug-In Hybrid Electric Vehicles or Battery Electric Vehicles Purchase Incentives
3. Clean Vehicles "Feebate" Program
4. Car Sharing
5. Smart Driving Strategy
6. Commuter Benefits Ordinance
7. Vanpool Incentives/Employer Shuttles

Each Climate Policy Initiative is summarized in the following pages, including a description of the project objective, contextual background, assumptions and methodology, analytic steps and results.

In addition to the seven Climate Policy Initiatives, the Proposed Plan and EIR alternatives include $226 million for the expansion of the current Climate Initiatives Innovative Grants program. The funding will be used to support the advancement of GHG emission reduction strategies that are currently being piloted. The most effective strategies will be improved upon and expanded as appropriate throughout the region. No emissions reductions credit (for the purposes of SB 375) is taken for the Innovative Grants projects since MTC has not yet determined which projects will be funded.

Emission Rates

To calculate the carbon dioxide (CO_2) emissions reductions from the Climate Policy Initiatives, the California Emissions Model (EMFAC2011) trip end emission rates and exhaust per mile emission rates for light and medium duty vehicles were used. The regional average for annual CO_2 emissions from light and medium duty vehicles are applied to the calculated trip reductions and VMT reductions, which are summarized in the individual policy descriptions below.

TABLE 14: CARBON DIOXIDE EMISSION RATES

	Year 2020	*Year 2035*
CO_2 Exhaust Emission Rate (grams per mile)	400.13	400.05
CO_2 Trip End Emission Rate (grams per trip)	86.16	86.55

Source: EMFAC2011

Note that these emission rates were not used for the vehicle strategies. The next section clarifies the baseline for the vehicle strategies.

Calculating the Baseline for Vehicle Strategies

In the following sections, we review three programs which focus on reducing GHG emissions by increasing the use of electricity as a transportation fuel, accelerating the deployment of electric vehicles with a fleet turnover program, and a clean vehicle feebate program. Unfortunately, EMFAC2011 does not include baseline assumptions regarding the vehicle fleet as a result of the Advanced Clean Cars Program. This program impacts the percentage of zero emission vehicles (ZEVs) that original equipment manufacturers (OEMs) are required to sell in California through 2025. As a result, MTC and ICF developed a baseline for vehicles and emissions using EMFAC2011 with several modifications, based in part on information released by ARB. The baseline for GHG emissions was developed using well-to-wheels emission factors rather than the tailpipe emission factors reported in EMFAC.

The following subsections outline the methodology employed to develop the baseline vehicle populations, including plug-in electric vehicles (PEVs), and associated GHG emissions in the nine Bay Area counties. Generally, a combination of data from EMFAC2011 and ARB documentation for the Advanced Clean Cars Program were used; these data were supplemented by assumptions to account for regulations such as Pavley Standards, the Low Carbon Fuel Standard (LCFS), and the ZEV Program.

Baseline Vehicles and GHG Emissions for the Bay Area

BASELINE VEHICLES

The number of vehicles reported in EMFAC2011 for the nine Bay Area counties was used to develop a baseline vehicle population. The analysis was limited to light-duty vehicles, including light-duty automobiles (LDA) and light-duty trucks (LDT1 and LDT2). New vehicles sales in the Bay Area were estimated based on statewide projected sales in 2011. Based on EMFAC and sales data from the

California New Car Dealers Association (CNCDA), it was estimated that the Bay Area accounts for approximately 21 percent of vehicle sales in California. It was also assumed that vehicle sales will increase at an annualized rate of about 0.5 percent out to 2035, based on growth rates extracted from EMFAC.

The analysis accounted for PEVs that would be deployed to meet the requirements of the ZEV Program, which requires automobile manufacturers to introduce zero tailpipe emission vehicles in volumes that increase over time. The program is implemented using credits, which vary depending on factors such as emission control technology and vehicle range. The analysis relied on ARB documentation describing the most likely compliance scenario[16] – a mix of transitional zero emission vehicles (TZEVs), battery electric vehicles (BEVs), and hydrogen fuel cell vehicles (FCVs). To develop the baseline, it was assumed that TZEVs would all be plug-in hybrid electric vehicles (PHEVs) and that the percentage of ZEVs sold in the Bay Area would be proportional to the percentage of total light-duty vehicles sold in the Bay Area compared to the entire state. We refer to this as a fair-share assumption; it is conceivable and even likely that, in the near-term, PEV sales will be proportionally higher in the Bay Area than other regions in California. However, with a 25-year timeline for the analysis (2010-2035), it is difficult to justify that the Bay Area will sustain higher PEV sales for the entire duration of the analysis.

Information presented by ARB on the updated ZEV Program was used to estimate the penetration of PHEVs, BEVs and FCVs out to 2025. Beyond 2025, it is assumed PEV sales as a percent of total vehicle sales will remain constant, since there is no regulatory driver for increased PEV sales post-2025. See Table 15 for penetration rates reported as new vehicle sales.

TABLE 15: PERCENT NEW VEHICLE SALES FOR BASELINE

Year	% new vehicle sales		
	PHEV	BEV	FCV
2020	5.2%	2.2%	0.6%
2035	9.2%	3.7%	2.6%

The ZEV Program includes provisions for OEMs to earn credits for over-compliance[17], as measured by grams of carbon dioxide per mile (gCO_2/mi). These over-compliance credits can effectively reduce the ZEV requirements for OEMs out to 2021, thereby decreasing the total number of PEVs. However, for the purposes of this exercise, it is assumed that OEMs will not use this as a compliance option.

We applied a vehicle turnover profile extracted from EMFAC to calculate the total number of PEVs (i.e., vehicle stock or total PEV population as opposed to new vehicles) over time. The turnover for PEVs will likely be different than for conventional vehicles, especially considering that the useful lifetime of batteries (in an automotive application) deployed today is unknown. However, we did not have sufficiently convincing data to modify the fleet turnover profile.

[16] Appendix B, Draft Environmental Analysis for the Advanced Clean Cars Program, CARB, December 2011. We also drew from an ARB Staff Presentation dated November 16, 2010 entitled "ZEV Regulation 2010, Staff Proposal", available online at: http://www.arb.ca.gov/msprog/zevprog/2011zevreg/11_16_10pres.pdf

[17] See Section 1962.2(d)(6)(C) of the Final Regulation Order for the Zero Emission Vehicle Regulation: 2018 and Subsequent Model Years for more information.

BASELINE GHG EMISSIONS

The GHG emissions attributable to light-duty vehicles in the Bay Area were estimated on a lifecycle basis. From the standpoint of developing PEV-related scenarios for the Sustainable Communities Strategy, it would be an apples-to-oranges comparison if we did not account for the upstream emissions of electricity used as a transportation fuel. The GHG reduction benefits of PEVs on a strictly tailpipe emissions basis are much more significant. Although the emissions were calculated on a lifecycle basis, we only considered CO_2 emissions as opposed to equivalent CO_2 emissions (CO_2e) in our estimates.

The GHG emissions attributable to light-duty vehicles are a function of vehicle fuel economy, the corresponding emissions factor(s) for the fuel(s) used, the vehicle miles traveled (VMT), and the vehicle lifetime.

To estimate the GHG emissions attributable to conventional vehicles using gasoline, PHEVs, BEVs, and FCVs, the carbon intensity values and the energy economy ratios (EERs) shown in Table 16 were used. For the most part, these values are either taken directly from or modified based on the LCFS documentation. The following adjustments and modifications were made:

- For reformulated gasoline, we accounted for the LCFS by subtracting the GHG reductions attributable to the baseline deployment of PHEVs, BEVs, and FCVs in the Bay Area and adjusting the carbon intensity of reformulated gasoline to reflect the remaining reductions required to comply with the regulation.
- For electricity, the carbon intensity of marginal electricity generation in California from CARB's LCFS look-up table and adjusted for CO_2 emissions only. ICF also accounted for compliance with the Renewable Portfolio Standard (RPS) in the calculation of the carbon intensity for electricity and assumed that PG&E would meet the 33 percent goal by 2020; as a result, the carbon intensity post-2020 was adjusted accordingly.
- In the case of hydrogen consumption in FCVs, we adjusted values in 2020 assuming that 50 percent of the hydrogen consumed was generated via on-site steam reformation using methane and that the remaining 50 percent was generated via on-site reformation using renewable feedstocks.

TABLE 16: CARBON INTENSITY VALUES USED FOR ANALYSIS

Fuel	Carbon Intensity (g CO2-eq/MJ) 2010-2020	Carbon Intensity (g CO2-eq/MJ) 2021+	EER[18]	Notes
Gasoline	92.59	92.59	--	Adjusted from CARB data to account for difference between CO_2e and CO_2
Electricity	98.94	79.27	3.4	Adjusted from CARB data to account for difference between CO_2e and CO_2; updated in 2020 to account for RPS
Hydrogen	126.78	85.23	2.5	Adjusted from CARB data to account for difference between CO_2e and CO_2; adjusted in 2020 assuming: a) 50% on-site NG reformation and b) 50% on-site reformation w/ renewable feedstocks

As a simplification, we assumed a constant annual per vehicle VMT of 12,333 miles. This value was agreed upon by ICF and MTC after considering the values extracted from EMFAC by vehicle age and the VMT employed by MTC's travel model. For PHEVs, we assumed that 30 percent of the VMT would occur in charge depleting mode or "all-electric" miles.

The annual GHG emissions for years 2015-2035 in 5-year increments are shown below in Table 17, reported in units of million metric tons (MMT).

TABLE 17: BASELINE GHG EMISSIONS FROM LDVS FOR THE BAY AREA

Year	GHG Emissions (MMT)			
	PHEV	BEV	FCV	Total LDV
2015	0.073	0.007	0.001	24.517
2020	0.201	0.022	0.003	20.291
2025	0.369	0.048	0.009	17.979
2030	0.582	0.077	0.008	16.709
2035	0.744	0.098	0.008	16.209

[18] See Table 5 in Proposed Regulation Order Subchapter 10, Article 4, Subarticle 7. Low Carbon Fuel Standard, Section 95485, October 2011.

Regional Charger Program

Plug-in electric vehicles (PEVs) have the potential to reduce GHG emissions in the transportation fuels sector significantly. Today, the Bay Area is the leading market for PEV sales, including both plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs). PHEVs have a hybridized powertrain which 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 PHEVs.

PHEVs have what is referred to as an all-electric range (when in charge depleting mode) of about 10-40 miles. For instance, the Toyota Prius Plug-in has an all-electric range of 11 miles; the Ford C-MAX Energi has an all-electric range of 21 miles; and the Chevrolet Volt has an all-electric range of 38 miles. It is generally assumed that most PEV owners will charge their vehicles at home. The charging equipment is referred to as electric vehicle supply equipment (EVSE). Although at-home charging provides the most convenient – and perhaps the most affordable – form of charging, by providing PEV drivers access to EVSE at workplaces, commuter hubs, and other destinations, the all-electric range of their vehicles can be extended. Miles traveled using electricity yield a larger GHG benefit.

The MTC *Travel Model One* simulation for year 2010 estimated an average distance from home to work for Bay Area commuters of 13 miles; these miles only include the distance between home and work and do not factor in any errands, or other trips that may extend the daily distance traveled. In other words, the average round-trip distance in the Bay Area in 2010 was about 26 miles. In some cases, e.g., with the Chevrolet Volt, there may be sufficient range to make these trips entirely using electricity. However, with increases in the sales of PHEVs with less than 25 miles of range, and several more PHEV models with similar ranges hitting the market soon, there is significant potential to extend the all-electric miles traveled in the Bay Area.

The objective of this program is to establish a regional public network of electric vehicle supply equipment (EVSE) for plug-in hybrid electric vehicles. However, the costs are often prohibitive and there are other barriers (e.g., on-site electrical capacity) that may limit the potential for deploying EVSE 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.

This program will also help support the objectives outlined in the Bay Area's PEV Regional Readiness Plan.[19] MTC works in partnership with the Bay Area Air Quality Management District (BAAQMD) regarding regional PEV readiness planning. The BAAQMD is leading regional efforts to ensure that local and regional governments are identifying the steps that they need to take to become PEV-ready. The readiness planning focuses on issues such as updating building codes, streamlining permitting and inspection processes, and modifying zoning, parking rules, and local ordinances as needed to support

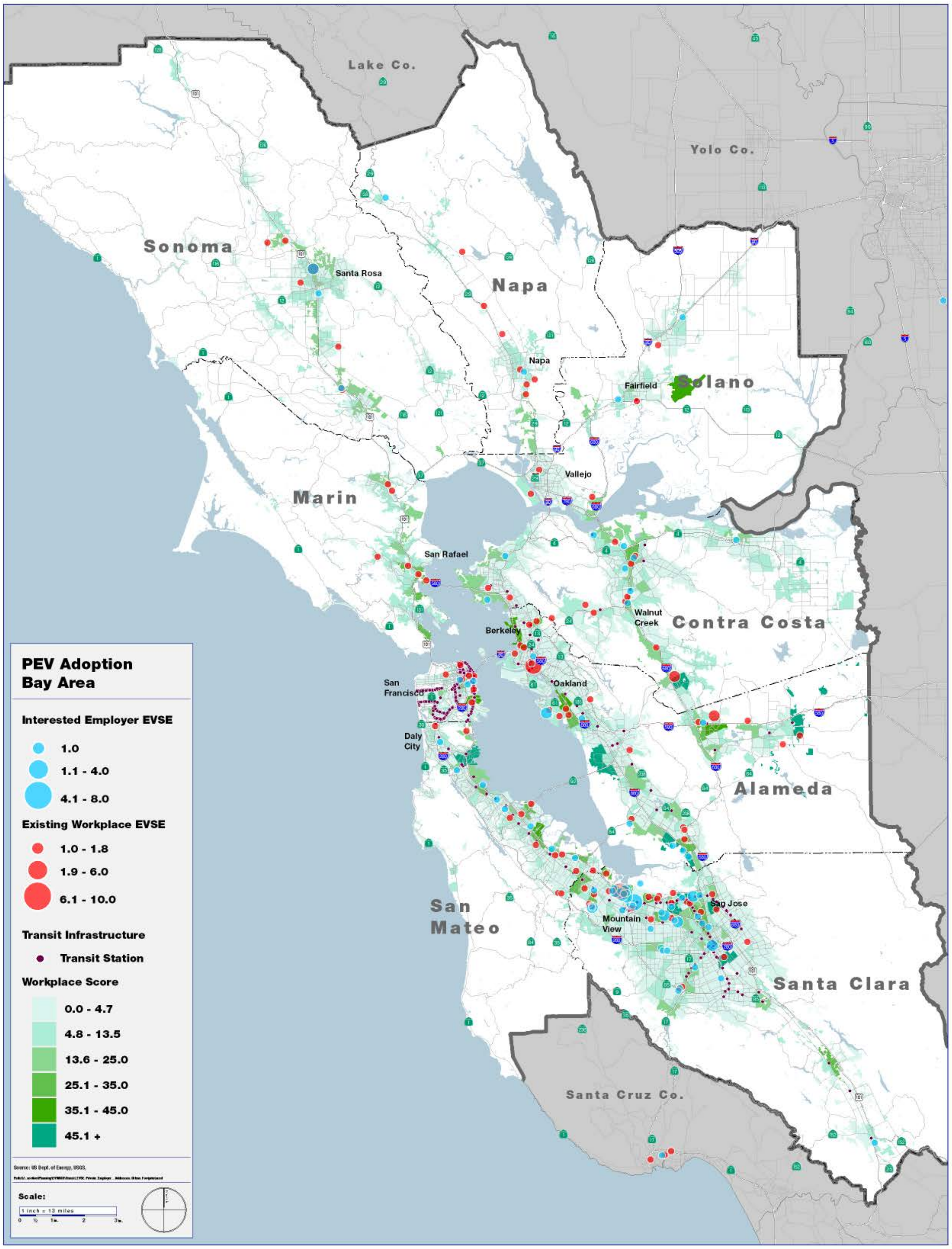
[19] Bay Area and Monterey Bay Area Plug-in Electric Vehicle Readiness Plan, Summary 2012. Prepared by ICF International for the Bay Area Air Quality Management District. Available online: http://www.baaqmd.gov/~/media/Files/Strategic%20Incentives/EV%20Ready/Summary%20PEV%20Readiness%20Plan%20FINAL.ashx

PEV deployment. The readiness plan also includes a siting analysis, which seeks to guide and coordinate future PEV charging infrastructure-siting efforts based on anticipated or projected demand for EVSE. The three major goals of the siting analysis were to:

- Provide charging opportunities for PEV owners that lack access to home charging;
- Extend the range of PEVs for intra- and inter-regional travel along various corridors; and
- Maximize all-electric miles by providing ample opportunities for charging while minimizing the risk of stranded PEVs.

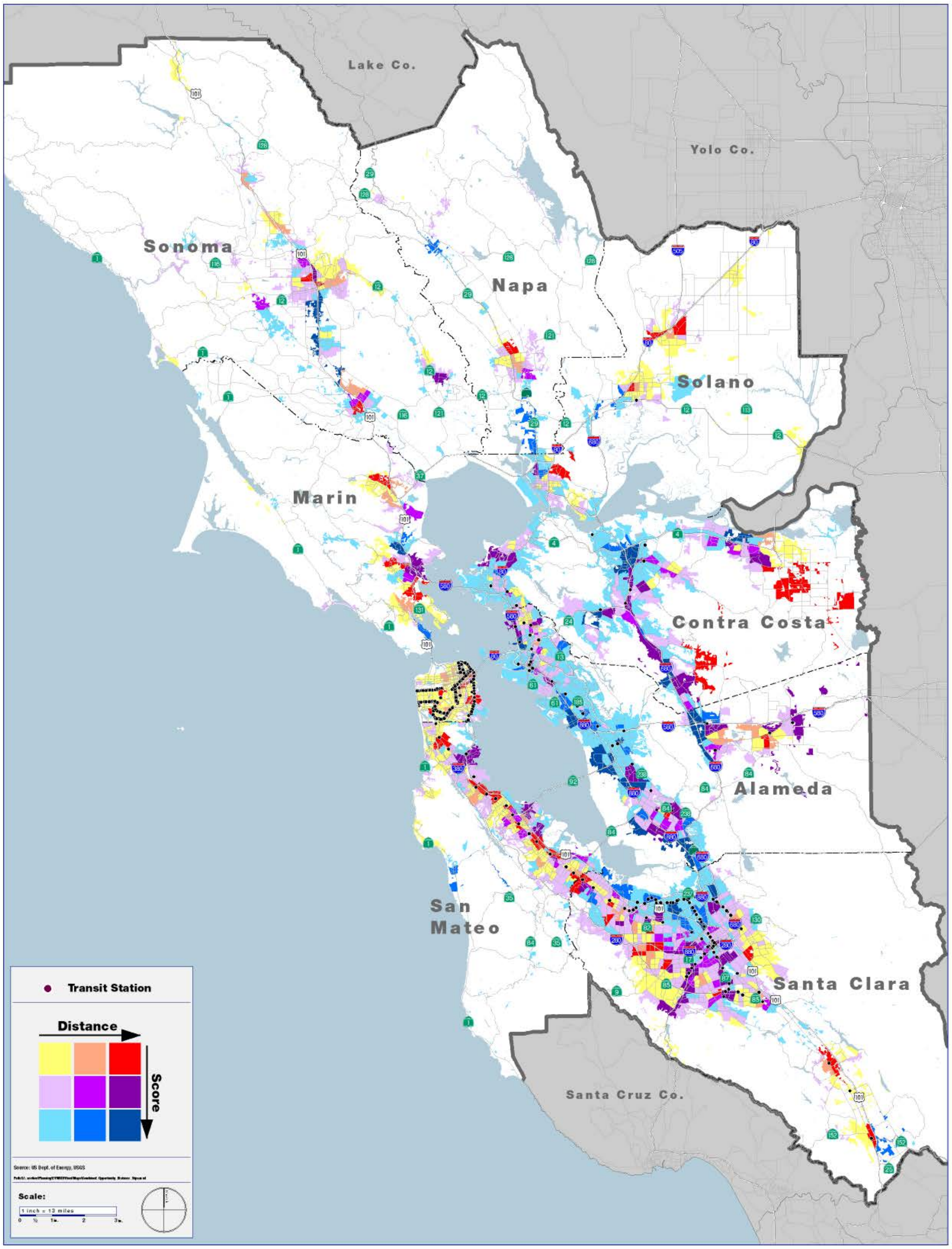
ICF worked with MTC to identify likely PEV adopters in the region. ICF, in partnership with Fehr & Peers, worked with MTC to use *Travel Model One* to identify the most likely destinations for PEV adopters. These destinations were characterized using trip purposes e.g., work, shopping, social/recreational, etc. The analysis focuses on workplace siting and opportunity charging. The two maps below are taken from the PEV Readiness Plan and show the results of the workplace siting analysis and the opportunity charging siting analysis:

- The map in Figure 27 below shows an overlay of the following data: the most likely destination zones for workplace trips (different shades of green), areas with existing workplace Level 2 EVSE (red dots), areas with employers interested in deploying workplace EVSE for employee charging (blue dots), and transit stations (purple dots).
- Opportunity charging is distinguished from residential and workplace charging and covers a wide range of situations where a PEV driver could potentially charge when away from home and/or work. Within this category, there are different sub-categories specific to the type of venue—such as retail parking lots, on-street parking, airport long- and short-term parking, cultural and/or recreational centers, etc. The legend in Figure 28 shows nine colors representing a matrix of scoring across three groups of distances and three groups of PEV-weighted trips. Each block or color in the horizontal direction (left to right) represents the following trip distances: 0-5 miles, 6-10 miles, and 11+ miles. Opportunity trips are generally in addition to other daily trips (e.g., home to work and work to home trips). Each block or color in the vertical direction (top to bottom) represents the highest number of trips by likely PEV adopters to that zone. In other words, the blue shaded zones (light, medium, and dark blue) represent the most trips by likely PEV adopters to that particular region.



Source: ICF, MTC GIS Unit; from Bay Area and Monterey Bay Area PEV Readiness Plan, Summary 2012

FIGURE 27: WORKPLACE SITING OF EVSE IN THE BAY AREA



Source: ICF, MTC GIS Unit; from Bay Area and Monterey Bay Area PEV Readiness Plan, Summary 2012

FIGURE 28: OPPORTUNITY CHARGING FOR LEVEL 2 EVSE

ASSUMPTIONS AND METHODOLOGY

In the baseline, it was assumed that 30 percent of miles traveled by PHEVs would be in charge depleting mode or electric miles. Based on the increased availability of EVSE throughout the Bay Area, this percentage is increased to 41 percent.

To increase the electric miles traveled by PHEVs, a regional network of charging infrastructure must provide drivers an opportunity to plug-in, particularly while at work, as this is where most vehicles will spend most of their time parked when not at home. Due to the focus on PHEVs, the regional EVSE network would provide incentives for the installation of Level 1 EVSE (75%) and Level 2 EVSE (25%).

With an upper limit of 16 kWh for the battery size of a PHEV, the time to recharge to full capacity is about 7 hours and 3 hours for a Level 1 and Level 2 EVSE, respectively.

This analysis assumes incentives of $250 for Level 1 EVSE installations and $2,100 for Level 2 EVSE installations.

There were no assumptions made regarding a shift in fleet make-up as a result of EVSE availability. It is conceivable that the increased availability of Level 2 EVSE could increase the sales of BEVs. However, this is difficult to justify as fast charging EVSE are more likely to induce demand than Level 2 charging. Similarly, there is a cap on the amount of credit that OEMs can earn as a result of selling PHEVs, so there is not a regulatory driver for increased PHEV sales beyond what was assumed in the baseline.

ANALYSIS STEPS

To determine the GHG emission reductions from EVSE deployment throughout the region, an emissions calculator for the Bay Area that was used to:

1. Modify the percentage of miles traveled in charge depleting mode from the baseline 30 percent to 41 percent.
2. Determine the GHG emissions reduction.
    a. The GHG emissions attributable to PHEVs are based on how many miles each vehicle spends in each mode (charge depleting or gas/diesel).
    b. The GHG emission reductions are determined as the difference between the emissions attributable to the PHEV versus the emission that would have otherwise occurred using an average conventional gasoline vehicle.
3. There were no changes made to the VMT.

On a strictly linear basis, about 20 to 25 percent of all PHEVs would require access to EVSE at any given time to achieve the increased electrification goal of this strategy. However, by 2035, we assume that EVSE will have improved capabilities and that it will be possible to plug-in multiple vehicles to a single charge point and stagger the charging so that each vehicle returns to full state of charge (SOC).

TABLE 18: REGIONAL CHARGER PROGRAM EMISSION REDUCTION BENEFITS

			EIR Alternative			
		No Project	*Proposed Plan*	*Transit Priority Focus*	*Enhanced Network of Communities*	*Environment Equity, and Jobs*
CO_2 Emissions Reductions	2020 Daily Short Tons Reduced	0	-76	-76	-76	-76
	2020 Percent Per Capita Reduction from 2005 Baseline	0%	-0.1%	-0.1%	-0.1%	-0.1%
	2035 Daily Short Tons Reduced	0	-282	-282	-282	-282
	2035 Percent Per Capita Reduction from 2005 Baseline	0%	-0.3%	-0.3%	-0.3%	-0.3%

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

COSTS

The costs of EVSE are a function of the level of charging (i.e., Level 1 or Level 2) and the total number of chargers required.

1. We estimate a ratio of approximately one EVSE for every five vehicles by 2035, consistent with charger-to-vehicle ratios estimated by EPRI for workplace and public charging opportunities and research conducted by ICF regarding charging optimization[20].
2. Multiply estimated number of EVSE by per EVSE incentive.

[20] D. Bowermaster, EPRI. *How Much Electric Vehicle Charging is Needed?* California Plug-in Electric Vehicle Collaborative Meeting, August 2012.

TABLE 19: ANTICIPATED NUMBER OF EVSE INSTALLATIONS AND COST

Year	Number of EVSE		Total Cost ($millions)
	L1	L2	
2020	10,800	3,600	$10.2
2035	62,800	20,900	$59.7

Total program costs are estimated at $80 million in year of expenditure dollars.

Vehicle Buyback & PEV Incentive

Plug-in electric vehicles are being adopted at significant levels today in the Bay Area. The ZEV Program and the LCFS in California are regulatory drivers for advanced vehicle technologies and alternative fuels. Despite the near-term success of PEVs in the Bay Area, sales are still relatively small and represent 0.5 percent of total new light-duty vehicle sales. There is also some uncertainty regarding the medium- to long-term availability of purchase incentives e.g., the federal tax credit and the California state rebate. Furthermore, one of the main drivers today for PEV sales, particularly for PHEVs, is HOV lane access: PHEVs are eligible for the green sticker (limited to the first 40,000 applicants through January 1, 2015) and BEVs are eligible for the white sticker and qualify through January 1, 2015. As of March 2013, nearly 11,000 green stickers have already been issued in California.[21]

Most analysts agree that the first adopters of PEVs will be higher income individuals who own their homes, and in many cases, own or have owned a hybrid electric vehicle e.g., a Toyota Prius. The higher purchase price of PEVs makes it difficult for middle and low income consumers to adopt a PEV. This program will provide a combination of an incentive of up to $2,000 to purchase a PEV along with the buyback of older, less efficient vehicles. This is intended to extend the market for PEVs into a broader range of income classes. 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, recent research from Polk has shown that owners of both new and used vehicles are holding on to their vehicles longer[22]. When compared to similar surveys in 2001, Americans are holding on to their cars for nearly two years longer. Additionally, ARB estimates that half of cars live to be 15 years old and one quarter live to be 20 years old. Interestingly, if a vehicle does survive to 20, there is a 40 percent chance it will be on the road for another ten years after that.[23] This will impact the turnover of the fleet significantly and may slow the purchase of new vehicles, including plug-in electric vehicles. The vehicle buyback program seeks to accelerate fleet turnover, while also incentivizing the purchase of advanced

[21] CARB Mobile Source Program: http://www.arb.ca.gov/msprog/carpool/carpool.htm. Accessed March 28, 2013.

[22] Americans are Holding their Vehicles Longer … is it Good for Loyalty? Blog post by L Miller at Polk, December 17, 2012. Available online at: http://blog.polk.com/blog/blog-posts-by-lonnie-miller/americans-are-holding-their-vehicles-longeris-it-good-for-loyalty

[23] Report to the California Legislature, Accelerated Light-Duty Vehicle Retirement Program. http://www.arb.ca.gov/research/apr/reports/l2070.pdf. Accessed March 20, 2013.

vehicle technology. Depending on the fuel economy threshold set by the program, the combination vehicle buyback and incentive program is intended to induce demand in middle and lower income brackets that might otherwise delay car purchasing, purchase a new conventional vehicle, or purchase a used vehicle.

Given the uncertainty regarding the medium- to long-term availability of incentives for PEV purchasing, and the potential interest from mid-adopters (e.g., middle income consumers), MTC is proposing to fund a vehicle buyback program. The program will be designed as a trade-in for older vehicles that meet a certain fuel economy threshold (as measured via miles per gallon, MPG). The consumer is only eligible for the trade-in if the new vehicle being purchased is a PHEV or BEV. The incentive amount will vary with the fuel economy of the vehicle being traded in (measured in MPG) as well as the vehicle type being purchased (e.g., PHEV or BEV).

The objective of the vehicle buy-back program is to provide an opportunity for consumers to trade-in an older, less efficient vehicle for a new PHEV or BEV.

ASSUMPTIONS AND METHODOLOGY

There are two aspects of a vehicle buyback program which will reduce GHG emissions: the first is attributable to the accelerated turnover of vehicles and the second is due to the accelerated deployment of PEVs.

- Implementation of this program will begin in 2020.
- 47,000 additional PEVs will be on the road by 2035, adding to the estimated 535,000 PEVs on the road in the Bay Area for the baseline scenario. This is a modest annual increase of about 0.5 percent in new vehicle sales attributable to the buyback incentive program.
- To estimate the GHG benefits of the accelerated turnover of vehicles as a result of the program, this analysis estimates a fleet average fuel economy improvement above EMFAC2011 estimates of 0.5 percent. The fuel economy improvement was estimated based on displaced older vehicles in the fleet (>10 years old).
- For the initial analysis, it is assumed that the deployed vehicles would be split 50/50 between PHEVs and BEVs.
- It is assumed that the incentive level would average about $1,000 per PHEV and $2,000 per BEV. However, the actual incentive will vary based on the MPG of the vehicle being traded in as well as the technology of the vehicle being purchased.

ANALYSIS STEPS

The analysis followed three steps to estimate the emissions reduced by the removal of old vehicles:

Removal of Old Vehicles

1. Decrease number of vehicles in the EMFAC2011 inventory that are older than 10 years based on estimated PEVs deployed as part of this program.
2. Estimate fuel economy improvement based on accelerated turnover.
3. Calculate GHG emissions of improved fleet fuel economy.
4. Calculate GHG emissions of increased PEVs deployed.

Introduction of PEVs

1. The GHG emission reductions were determined as the difference between the emissions attributable to the PEV versus the emission that would have otherwise occurred using an average conventional gasoline vehicle. For the PHEV this depends on the proportion of time spent in charge depleting mode versus gas/diesel mode.

TABLE 20: VEHICLE BUY BACK AND PEV INCENTIVE PROGRAM EMISSION REDUCTION BENEFITS

		EIR Alternative				
		No Project	*Proposed Plan*	*Transit Priority Focus*	*Enhanced Network of Communities*	*Environment Equity, and Jobs*
CO_2 Emissions Reductions	2020 Daily Tons Reduced	0	0	0	0	0
	2020 Percent Per Capita Reduction from 2005 Baseline	0%	0%	0%	0%	0%
	2035 Daily Tons Reduced	0	-470	-470	-470	-470
	2035 Percent Per Capita Reduction from 2005 Baseline	0%	-0.5%	-0.5%	-0.5%	-0.5%

Due to the 2020 program start date, no emission reduction benefits are included for the year 2020. Emission reductions are consistent across all EIR alternatives because the analysis does not rely on inputs from the travel model.

COSTS

The costs of the program are two-fold: a) the monetary value of the incentives deployed and b) the costs of administering the program

- We determined the costs of the incentives by multiplying the number of PHEVs and BEVs deployed (assumed 50/50 split) as part of program by incentive level ($1,000 and $2,000, respectively).
- The administration costs were assumed to be 5% of the costs of the incentives; this is consistent with the level of administrative support required for programs such as the Hybrid Truck and Bus Voucher Incentive Program and the Clean Vehicle Rebate Project.

Total escalated YOE costs are $120 million.

Clean Vehicles Feebate Program

Originally coined in the 1990s, feebate programs have typically been used to shift buying habits in the transportation and energy sectors. MTC is proposing to use a feebate program to incentivize consumers to scrap older vehicles and purchase higher performing, cleaner vehicles. A feebate programs uses a combination of fees and rebates to change consumer behavior. Consumers purchasing a vehicle that emit more CO_2 on a gram per mile basis than a defined standard are assessed a fee at the point of purchase. These fees are used to provide rebates to consumers that purchase vehicles that emit less CO_2 on a gram per mile basis than the defined standard.

Feebates have been used with some success in other countries, including Denmark, France, the Netherlands, and Norway. The structure of a feebate program for California was studied in considerable detail for the ARB[24]. In fact, California has come close to implementing a statewide feebate program on multiple occasions through legislative efforts – the first time in the early 1990s and more recently in 2008. In California, feebate programs have been proposed as a legislative initiative (e.g., AB 493 Ruskin in 2007), whereby implementation authority would be delegated to ARB and the State Board of Equalization. Moving forward, MTC will have to engage with ARB and the local air district, Bay Area Air Quality Management District (BAAQMD) to determine how the program would be implemented. Ultimately, it is conceivable that MTC would need to seek action via the Legislature to approve of a regional feebate initiative. A feebate program is not dissimilar from the fee that was approved by the Legislature via AB 434 (Sher, Chapter 807, Statutes of 1991) establishing the Transportation Fund for Clean Air (TFCA).

ASSUMPTIONS AND METHODOLOGY

The analysis draws heavily from results reported by Bunche and Greene's feebate analysis for the ARB. The major benefits of the feebate programs analyzed by Bunch and Greene are attributable to the first several years of the program. In that report, the authors state: "In later years the level of GHG emissions reduction relative to the standard diminishes as the standard becomes more stringent."

It is assumed that the feebate program is introduced in 2020 and that there are not any increases in fuel economy standards at the state- or national-level after 2025. To maintain consistency with the Bunch and Greene study, this analysis assumes a $20 per g/mi feebate rate in a single benchmark system. Based on a sensitivity analysis performed by Bunch and Greene, an increase to $30 per g/mi feebate rate will yield a 50 percent increase in GHG reductions.

This analysis also assumes that the program is designed to be revenue neutral, but that administrative costs are covered by MTC. Bunch and Greene estimate about $4.6 to$6.5 million annually for a statewide

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[24] Greene, David L. and Bunch, David S., "Potential design, implementation, and benefits of a feebate program for new passenger vehicles in California", Prepared for the California Air Resources Board, Contract UCD 08-312, February 2011.

program with an additional $2 to $4 million in startup costs. The program largely scales linearly with the total fees collected, estimated at about 1 percent of total fees collected. This analysis assumes that the Bay Area represents about 20 percent of the entire California market.

ANALYSIS STEPS

The GHG emission reductions were calculated in the following steps:

1. Estimated the improvement in fuel economy (back-calculated based on grams per mile estimates) of the new vehicle fleet due to the feebate program. Maximum improvement at the outset of the program is about 4.2 percent; by 2035, the improvement is reduced to 2.3 percent.
2. Based on vehicle turnover, estimate modified fuel economy of entire fleet after change to improved fuel economy of new vehicles as of 2020 due to feebate program.
3. Calculate differential in well-to-wheels GHG emissions of modified fleet versus baseline fleet.

TABLE 21: CLEAN VEHICLE FEEBATE EMISSION REDUCTION BENEFITS

			EIR Alternative			
		No Project	*Proposed Plan*	*Transit Priority Focus*	*Enhanced Network of Communities*	*Environment Equity, and Jobs*
CO_2 Emissions Reductions	2020 Daily Short Tons Reduced	0	0	0	0	0
	2020 Percent Per Capita Reduction from 2005 Baseline	0%	0%	0%	0%	0%
	2035 Daily Short Tons Reduced	0	-587	-587	-587	-587
	2035 Percent Per Capita Reduction from 2005 Baseline	0%	-0.7%	-0.7%	-0.6%	-0.7%

Due to the 2020 program start date, no emission reduction benefits are included for the year 2020. Emission reductions are consistent across all EIR alternatives because the analysis does not rely on inputs from the travel model.

COSTS

The costs of the program are estimated using parameters outlined in the Bunch and Greene analysis. They identified start-up costs and annual costs. Both are scaled to the size of Bay Area market, assuming that the cost of the program scales with the total fees collected. Total year of expenditure costs are $25 million.

Car Sharing

Car sharing allows individuals to rent vehicles by the hour, thus giving them access to an automobile without the costs and responsibilities of individual ownership. Car sharing is growing rapidly in the Bay Area both in traditional for profit/non-profit services (City CarShare, Zipcar, U Car Share, WeCar), new peer-to-peer car sharing (Getaround, RelayRides) and 1-way car share services (BMW DriveNow).

Traditional car sharing businesses operate on a membership basis. Users pay an annual fee in addition to hourly and sometimes per mile rates. Gas, maintenance, parking, insurance, and 24-hour access is all included in the membership and usage rates for car sharing. The pricing scheme is set up to encourage the use of the vehicles for errands, picking people up from the airport, and other short trips. For trips longer than one day it is usually less expensive to rent a vehicle through a car rental agency. It works best for households in neighborhoods that are highly served by transit where vehicles are only infrequently needed. After joining a car sharing program, households in these neighborhoods can often shed all vehicles and just participate in car sharing. In less dense neighborhoods car sharing may allow a two or three car family to shed one car and then use car sharing for the rare times that multiple vehicles are needed at the same time. In general, members are required to have a clean driving record and be over the age of 18 in order to join. Businesses are also signing up for business memberships to avoid maintaining a company fleet of vehicles.

Peer-to-peer car sharing (also known as P2P) allows an individual to rent out his/her private vehicle when not in use. This generates income for the owner and provides a wide range of vehicle types and prices to the renter. Peer-to-peer is more likely to succeed in less dense, suburban neighborhoods since the service is simply providing extra cash to the owners and does not require the vehicles to turn a profit over their cost of ownership. One such peer-to-peer company, Getaround, was launched in 2011 and has already built an extensive and rapidly growing network of vehicles.

One-way car sharing allows a driver to pick up a vehicle in one location and drop it off at another pod or in some cases, wherever is convenient within a set geographic area. This could allow an individual who took transit to work to then pick up a vehicle and run errands on the way home and leave the car parked by his/her home. This also allows the vehicles to turn over more frequently since users can drive to an event, park the car, let someone else rent it, and then pick up a different vehicle nearby for their return trip. One-way car sharing is just beginning in the Bay Area with the BMW all electric vehicle DriveNow system. There is also a scooter car sharing system in San Francisco named Scoot which operates a one-way program. In other markets such as San Diego and Austin there are successful one-way, all electric vehicle car sharing programs operated by Mercedes-Benz called Car2Go.

Car sharing has positioned itself to cause a major shift in the market that is not explicitly captured in *Travel Model One*. In the United States, there are currently over half a million car sharing members; this could swell to over 600,000 in 2013[25]. Based on the average number of members per car sharing vehicle we estimate that there are over 60,500 car sharing members currently in traditional Bay Area car sharing

[25] Bieszczat, Alice and Joe Schwieterman. "My Car, Your Car." Planning May/June 2012: 37-40.

schemes[26]. There are already thousands of vehicles available to serve those members. Car sharing helps to enable and expand the trend of younger generations putting off obtaining licenses and purchasing vehicles. Sharing rather than owning is becoming ever more popular. "FORBES estimates the revenue flowing through the share economy directly into people's wallets will surpass $3.5 billion this year, with growth exceeding 25percent. At that rate peer-to-peer sharing is moving from an income boost in a stagnant wage market into a disruptive economic force."[27] Additionally, with increasing and volatile fuel prices the overall cost of auto ownership is increasing and there are uncertainties regarding operating expenses that many people would prefer to not deal with. Car sharing eliminates these concerns.

Car sharing reduces emissions 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 (see assumptions and methodology for more details).

MTC can help encourage car share expansion by providing support for new pods and services in the North Bay, South Bay and inland East Bay.

ASSUMPTIONS AND METHODOLOGY

Under traditional car sharing models, estimates of the likely population to adopt car sharing ranges from 10 percent[28] to 13 percent[29] of the eligible population. The eligible population is defined as adults between the ages of 20 and 64 (56 percent of the total projected 2035 Bay Area population). With the introduction of one-way and peer-to-peer car sharing MTC assumes that adoption rates will reach 15 percent of the eligible population in dense urban areas by 2035. It is assumed that a much lower adoption rate of 5 percent of the eligible population could adopt car sharing by 2035 in suburban areas. These increased adoption rates across the board are assumed to be influenced by the expansion of peer-to-peer car sharing and one-way car sharing as well as the introduction of MTC subsidies. For a full set of the adoption rate assumptions see Table 22 below.

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[26] Estimated to be 1,200 vehicles in the Zipcar and City CarShare fleet in 2012. With an average of 49 members/vehicle (Shaheen, S.A., Cohen, A, and Chung, M. (2009). North American Carsharing: 10-Year Retrospectie, Transportation Research Record: Journal of the Transportation Research Board, No. 2110, Transpotation Research Board of the National Academies, Washington, DC, pp. 35-44) that places the Bay Area traditional car sharing membership at 60,500.

[27] Geron,Tomio. "Airbnb and the Unstoppable Rise of the Share Economy". Forbes, February 11, 2013.

[28] Zipcar. http://www.zipcar.com/is-it/greenbenefits. Accessed December 7, 2012.

[29] Zhou, B., Kockelman, K, and Gao, R. "Opportunities for and Impacts of Carsharing: A Survey of the Austin, Texas Market", TRB, 2009.

TABLE 22: CAR SHARING ADOPTION RATES

EIR Alternative	*Urban Areas (UA)*	*Suburban Areas (SA)*
No Project (2020 and 2035)	10%	0%
All Other Alternatives (2020)	15%	0%
All Other Alternatives (2035)	15%	5%

Urban areas are defined as areas with a population density of at least ten people per residential acre. All other areas are considered suburban areas.

Research by Robert Cervero[30] indicates that on average car share members drive seven fewer miles per day than non-members. This is mostly due to the members who shed a vehicle after joining car sharing. Their daily VMT drops substantially and outweighs the increase in VMT from car share members that previously did not have access to a vehicle. In addition to this reduction in VMT, when members drive in car share vehicles, their per-mile emissions are lower because car share vehicles are more fuel efficient than the average vehicle. Research by Martin and Shaheen[31] shows that the car share fleet uses 29 percent less fuel per mile, a difference we assume will persist through 2040.

ANALYSIS STEPS

VMT Reduction

1. For the analysis year, calculate the residential density (RD) of every TAZ (transportation analysis zone).

$$RD_{TAZ} = \frac{Total\ Poplation_{TAZ}}{Residential\ Acres_{TAZ}}$$

2. Calculate the total car sharing eligible population (EP) in TAZs with a RD >10 (Urban Areas or UA) and with a RD <10 (Suburban Areas or SA).

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

[31] Average US/Canada mpg from Martin and Shaheen, MTI report, page 65

$$EP_{UA} = \sum_{TAZ=1}^{1454} \sum_{RD>10} \sum_{age=20}^{64} Population$$

$$EP_{SA} = \sum_{TAZ=1}^{1454} \sum_{RD<10} \sum_{age=20}^{64} Population$$

3. Calculate future car share membership population (MP) using Table 22 to determine the appropriate car share adoption rate assumption.

$$MP = EP_{UA} \times Adoption\ Rate_{UA} + EP_{SA} \times Adoption\ Rate_{SA}$$

4. Calculate the daily VMT reduction assuming 7 miles shed per day per member[32].

$$VMT = MP \times 7$$

Emissions Reduction

1. Calculate emission benefit of VMT reduction using EMFAC 2011 Exhaust Emission Rates.

$$Emissions_{VMT} = VMT \times Exhaust\ Emission\ Rate$$

2. Calculate the total annual miles driven in car share vehicles in the Bay Area by multiplying the Membership Population (MP) estimate by 1,200 annual miles per member[33]. Then use the annual miles to calculate the daily miles.

$$Annual\ Miles = MP \times 1200$$
$$Daily\ Miles = Annaul\ Miles/365$$

3. Calculate the emission benefit of the 29% more efficient car sharing fleet[34] from the emissions using EMFAC 2011 Exhaust Emission Rates.

$$Emissions_{Effeciency} = Daily\ Miles \times MP \times Exhaust\ Emission\ Rate \times 0.29$$

4. Sum the two sources of daily CO_2 emission reduction.

$$Emissions_{Total} = Emissions_{VMT} + Emissions_{Effeciency}$$

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

33 Estimate based on Martin and Shaheen, MTI report, 2010 (Figure 7).

34 Average US/Canada mpg from Martin and Shaheen, MTI report, page 65

TABLE 23: CAR SHARING EMISSIONS REDUCTION BENEFITS

			EIR Alternative			
		No Project	*Proposed Plan*	*Transit Priority Focus*	*Enhanced Network of Communities*	*Environment Equity, and Jobs*
CO_2 Emissions Reductions	2020 Daily Short Tons Reduced	-1,294	-2,040	-1,905	-2,032	-1,922
	2020 Percent Per Capita Reduction from 2005 Baseline	-1.6%	-2.6%	-2.4%	-2.5%	-2.4%
	2035 Daily Short Tons Reduced	-1,550	-2,346	-2,248	-2,355	-2,259
	2035 Percent Per Capita Reduction from 2005 Baseline	-1.8%	-2.6%	-2.6%	-2.6%	-2.6%

COSTS

MTC is proposing to provide funding to start-up car share offices in the North Bay and South Bay and support car share pods in lower density areas. Costs are estimated at $1,769,000 for an office or 6-8 pods (15 cars)[35]. Assume investment needed for offices or pods in:

- Sonoma and Marin Counties
- Napa and Solano Counties
- Eastern Contra Costa County
- Eastern Alameda County
- I-880 Corridor
- South Bay
- Peninsula

Total program cost in year of expenditure dollars is $13 million.

Smart Driving Strategy

Changing habits is not easy, but our country has been successful at changing ingrained habits before. Over the past four decades, we have seen smoking rates decrease and recycling rates increase, through

[35] Based on City CarShare grant application to MTC

awareness, government programs, and application of tools to assist with changing habits. Driving, like recycling, is a habit ingrained through years of unconscious action. Smart driving is a shift in our ingrained driving behavior through conscious choice, creating change that may one day become as natural as recycling a soda can.

To use a much relied upon analogy, there are multiple legs to the vehicle emissions reduction stool. The first is vehicle technology, the second is cleaner fuels, and the last is driver behavior. The state and federal government are tackling the critical first two legs. The low carbon fuel standard will rapidly decrease the carbon intensity of our fuels. On the vehicle side, increasingly stringent MPG and CO_2 requirements have been put in place through vehicle model year 2025.

SB 375 tackles the last leg of vehicle emissions reduction, driver behavior, from one direction – trying to create a more efficient land use pattern by locating housing closer to jobs and creating complete communities. This allows people to travel less in order to get to the jobs, goods, and services that they require. In addition to changing how *much* someone drives, people can change *how* they drive through training in the techniques of smart driving. Smart driving behaviors are easy-to-implement actions (e.g., change in driving style, vehicle maintenance, etc.) that any driver can do.

Researchers have proven that it is possible to affect significant and swift reduction in emissions through behavior change. This behavioral wedge, they argue, buys us time as policies we put in place take time to have an effect[36]. Smart driving is a good example of how behavior change can quickly reduce emissions.

Smart driving is starting to pick up a larger following around the world and is even inspiring technology startups in the Bay Area. One promising new technology which has recently received significant press and an overwhelming interest from the public is Automatic, which provides real time information on fuel efficiency on your smart phone along with calling 911 in a crash, deciphering the meaning of the "check engine" light, and remembering where you parked[37]. It has been reviewed by Wired, CNBC, ABC, PC Magazine, CNET and others as being a "visionary gadget" that "could change the way you drive".

The Metropolitan Washington Council of Governments (MWCOG) in Washington, D.C. completed an analysis of what it would take to meet their GHG goals. The most cost effective and productive strategy that could be implemented at the regional or local level was smart driving[38]. For this reason, MWCOG joined in partnership with the Delaware, Maryland, New York, North Carolina, New Jersey, and Massachusetts Departments of Transportation, along with several other MPOs and Port Authorities to launch the I-95 smart driving (which they refer to as eco-driving) campaign[39].

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[36] Community Based Social Marketing website, Fostering Sustainable Behavior, http://www.cbsm.com/pages/guide/fostering-sustainable-behavior/, accessed April 26, 2012

[37] http://www.automatic.com/

[38] "Meeting Transportation Greenhouse Gas Reduction Goals in the National Capital Region: A 'What Would it Take' Scenario". http://www.mwcog.org/clrp/elements/scenarios/whatwoulditakeTPB_TRB_Resubmit.pdf . Accessed March 20, 2013.

[39] http://www.i95coalition.org/i95/CoalitionEcoDrivingCampaign/tabid/216/Default.aspx

The largest smart driving study undertaken to date was by Fiat in 2010. The study analyzed the effects of their eco:Drive software with 5,700 drivers, over 428,000 journeys, 150 days and five countries. Their study required that participants use a USB drive plugged into the vehicle's data port when driving and then transfer the USB to a computer when they wanted to view their results and tips on improvement. Over the course of the study, the average improvement in fuel economy was six percent. The top ten percent of participants improved their fuel efficiency by 16 percent[40]. Based on the positive results of this study, Fiat has continued to expand their eco:Drive software to include in-vehicle displays and real time mobile apps. These improvements are mirrored in the technology that MTC is testing in their smart driving pilots (see below for more information). It is expected that with real-time feedback on driving habits, improvements in fuel efficiency could exceed the six percent seen in the initial study.

While there have been recent studies in the United States on smart driving, they have all been conducted with small sample sizes of twenty participants or less. Once outliers are removed from the data there is a low level of confidence in the results. In order to learn more about the potential of smart driving in the Bay Area, MTC is implementing the following smart driving pilots:

1) In-vehicle devices, displaying real time miles per gallon (MPG) and/or feedback on efficient acceleration, deceleration, and maintaining a steady speed. These devices are mounted on the dashboard of the participants' vehicles; and
2) MPG mobile apps, similar to the in-vehicle device pilot in a telephone app format. This pilot will be conducted in conjunction with ITS-UC Davis.

The in-vehicle display is connected to the vehicles OBD port and is receiving information from the vehicles computer system through the OBD port in real-time to inform the display. The smart phone app version calculates the drivers behavior based on the phone's GPS system. In both pilots, baseline driving habits over the course of at least one month will be collected. The devices will be in the participants vehicles for a minimum of three months to see how quickly the smart driving habits are learned and if the behaviors persist over time.

Each pilot will be evaluated for its ability to effect change in pilot participant's behavior and, ultimately, reduce GHG emissions. The results of this pilot will inform the future program implementation.

Currently, MTC is planning on implementing two main smart driving programs. The first is a social marketing campaign that will aim to teach drivers the basics of smart driving in-vehicle and maintenance behaviors in addition to trip linking and route planning. MTC currently offers several trip planning tools through www.511.org. For drivers, there is a real time and predicted future traffic information page which allows drivers to plan their trips to avoid congested routes. Trip linking is the practice of combining several trips into one larger trip by not returning home (or back to work) between locations. This smart driving technique focuses on eliminating vehicle miles traveled rather than improving fuel economy.

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[40] EcoDriving Uncovered: The benefits and challenges of ecodriving, based on the first study using real journey data. http://www2.fiat.co.uk/uploadedFiles/Fiatcouk/Stand_Alone_Sites/EcoDrive2010/en/ECO-DRIVING_UNCOVERED_full_report_2010_EN(1).pdf. Accessed March 20, 2013

The second smart driving program is a rebate program for fuel efficiency meters. Under this program MTC will offer a $100 rebate to consumers who purchase an OBD-connected after-market device. This device would be very similar to the in-vehicle devices being tested through MTC's two pilots. The real-time information on efficient driver behavior will quickly train drivers to alter their behavior in order to save money and gas, and reduce emissions.

ASSUMPTIONS

Social Marketing

In February 2011, MTC conducted a Baseline Climate Initiatives Survey which asked Bay Area residents about the ease of adoption of various emission reducing behaviors[41]. Behaviors targeted in this campaign were selected from the results of the survey.

In the survey, 55 percent of participants stated that it would be Very Easy or Easy to practice "smooth acceleration and deceleration and staying at or below the speed limit". The United States Department of Energy reports on their website that rapid acceleration and deceleration, and speeding can lead to fuel economy reductions from 5 percent on city streets to 33 percent on freeways[42]. For this program, it is assumed that between in-vehicle driver behavior, increased vehicle maintenance, and a series of other smart driving strategies that will be promoted through social marketing, residents can improve their fuel efficiency by 10 percent.

In MTC's Baseline Climate Initiatives Survey, 60 percent of participants stated that it would be Very Easy or Easy to practice "at least once per week, link several trips together, such as going shopping and to the post office, that you would normally make separately." For purposes of this analysis, that statement is interpreted to mean that due to the social marketing campaign the driver will link 3 shopping trips per week (effectively reducing 2 trips).

In MTC's Baseline Climate Initiatives Survey, 57 percent of participants stated that it would be Very Easy or Easy to practice "Using trip planning applications that plan your trips to ensure that you use the shortest routes and avoid traffic." By avoiding congested routes and eliminating idling in traffic it is assumed that drivers can improve their fuel efficiency by 5 percent, which is on the low end of research conducted by Facanha[43].

This campaign would be implemented through a traditional media format as well as social marketing. Preliminary estimates indicate $1 million of advertising can purchase 8,000,000 TV views, 5,000,000 radio listeners and 15,000,000 online hits. The public needs to see/hear an advertisement multiple times before

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[41] MTC conducted a Baseline Climate Initiatives Survey in February 2011. It was a 15 minute random digit dial and cell phone sample of Bay Area driving age residents. It was offered in English, Mandarin, and Spanish and had an overall margin of error of ±3.5%.

[42] US Department of Energy, Office of Energy Efficiency and Renewable Energy, US Environmental Protection Agency, *Model Year 2005 Fuel Efficiency Guide,* DOE/EE-0302

[43] Cristiano Facanha, "Effects of Congestion and Road Level of Service on Vehicle Fuel Economy", Transportation Research Board's 88th Annual Meeting, Paper 09-0268, Washington, D.C. National Academy of Science, 2009.

recognizing the message and being able to practice the requested behavior change. It is assumed that 12 views are needed before the resident will internalize the message.[44]

After a message is internalized the viewer must decide if this behavior is consistent with their lifestyle and/or self-image. It is assumed that the same percentage of the population that stated in the MTC Baseline Climate Initiatives Survey that the given behavior would be "easy" or "very easy" to adopt could adopt the behavior after internalizing the campaign message. This pool of residents who internalize the message and find the behavior easy to adopt are the potential adopters.

In order to adopt the desired behavior a resident must not only view the campaign and find the behavior easy to adopt but also be motivated to make a change (assuming that they were not practicing the desired behavior before viewing the campaign). Due to these limiting factors this analysis assumes that only 10% of people who viewed the campaign and stated that the behavior adoption would be easy actually adopt the behavior. It is assumed that the same total number of drivers will be practicing the behavior in 2020, 2035, and 2040. The campaign will be maintained throughout this time period so although some participants may stop practicing the behaviors, others will join over time in order to maintain a consistent program size.

After a strong four year campaign the annual funding would be reduced from $5 million/year to $2 million/year.

Fuel Economy Meters

Under this program MTC would offer a $100 rebate to consumers who purchase an OBD-connected after-market device similar to Automatic[45] and the ones tested in the MTC pilots. Based on the Fiat study and a study by the National Renewable Energy Laboratory (NREL)[46] on various driver feedback devices, this analysis assumes a 5.6 percent fuel economy improvement in every vehicle that a rebate is provided for. This is lower than the fuel economy improvements for the social marketing campaign since the real time device only provides guidance on acceleration, deceleration, and shifting while the social media campaign includes vehicle maintenance, weight, aerodynamics and other tips.

This incentive level can lead to the purchase of 900,000 in-vehicle devices for a $105 million in year-of-expenditure (YOE) dollars. It may be difficult to deploy this many in-vehicle devices through an MTC program; however, as auto manufacturers integrate more screens and technology into their vehicles some of this smart driving information is being included as an optional screen. This would allow more residents to receive feedback on their driving behaviors and teach them to correct inefficient behaviors. If redemption of the in-vehicle device rebates slows then this strategy could switch to a marketing campaign to encourage residents to use their vehicles built in technology to hone their smart driving skills.

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[44] The estimated number of views needed for the target audience to engage with the message varies dramatically by the medium and quality of the creative, but 12 views is seen as relatively standard conversion rate by marketing firms such as RHDG and Wit Media.

[45] http://www.automatic.com/

[46] Jeffrey Gonder, Matthew Earleywine, and Witt Sparks, "Final Report on the Fuel Saving Effectiveness of Various Driver Feedback Approaches", National Renewable Energy Laboratory, NREL/MP-5400-50836, March 2011

ANALYSIS STEPS

Social Marketing Campaign Reach

Steps 1-4 are used for each of the three social marketing elements (abbreviated as El). The social marketing elements include driving behavior (DB) such as acceleration, deceleration and maintenance, route planning (RP) to avoid traffic, and trip linking (TL).

1. Calculate the annual number of advertisement impressions assuming 8,000,000 TV views, 5,000,000 radio listeners and 15,000,000 online hits per $1,000,000 spent advertising each strategy.
$$Impressions_{El} = Budget_{El} \times (TV + radio + internet)$$

2. Calculate the number of targeted impressions assuming 12 views are needed/impression.
$$Targeted_{El} = Impressions_{El}/12$$

3. Of the targeted impressions, calculate the number that view the behavior as "easy" or "very easy" based on MTC's Baseline Climate Initiatives Survey. This response ranged from 56 to 60 percent depending on the program element. These are referred to as the potential adopters.
$$Potential_{El} = Targeted_{El} \times Survey_{El}$$

4. Of the potential adopters, calculate the number of actual adopters assuming 10% of the potential adopters carry through to adopt the behavior.
$$Adopters_{El} = 0.1 \times Potential_{El}$$

Trip Linking (TL)

5. Multiply the number of trip linking behavior adopters by the number of trips they are assumed to eliminate per week (2 trips/week)
$$Trips_{week} = Adopters_{TL} \times 2$$

6. Divide the number of trips per week by seven to obtain the daily trips reduced.
$$Trips_{day} = \frac{Trips_{week}}{7}$$

7. Multiply the number of eliminated trips by the average shopping trip length (~4 miles) from MTC's travel demand model to determine the daily VMT reduced from trip linking.
$$Miles_{TL} = Trips_{day} \times Length_{shopping}$$

Emissions Reductions

Trip Linking

a) Calculate the emissions reduction using EMFAC 2011 trip end and exhaust emission rates.
$$Reduction_{TL} = Trips_{day} \times Trip\ End\ Rate + Miles_{TL} \times Exhaust\ Rate$$

Route Planning (RP), Driving Behavior (DB), and In-Vehicle (IV) MPG Meters

a) Obtain the average daily VMT/person and VMT/vehicle from MTC's Travel Model One.

b) Calculate the daily miles that will be affected by the program by multiplying the number of people adopting the behavior or vehicles installed with real-time displays by the VMT/person or VMT/vehicle respectively.

$$Miles_{RP} = Adopters_{RP} \times VMT_{person}$$
$$Miles_{DB} = Adopters_{DB} \times VMT_{person}$$
$$Miles_{IV} = Rebates \times VMT_{vehicle}$$

c) Calculate the daily CO_2 emissions prior to adoption of the campaign elements (El) by applying EMFAC 2011 emission rates.

$$Emissions_{El} = Miles_{El} \times Exhaust\ Rate$$

d) Solve the equation below for **y**, substituting the expected percent increase in fuel economy of the various strategies for **x** (these values can be found in the assumptions section).

Greenhouse Gas Emissions and Fuel Economy Relationship Curve Equation[47σ]

$$y = -0.0062x^2 + 0.9832x - 0.7206$$

x = % increase in fuel economy

y = % reduction in fuel consumption or CO_2 emissions

e) Calculate the daily emissions reductions by applying the calculated value of **y** (the percent reduction in CO_2) to the original daily CO_2 emissions from the vehicles [step c].

$$Reduction_{El} = y_{El} \times Emissions_{El}$$

f) Sum the emissions reduction from all strategies.

$$Reduction_{Total} = Reduction_{TL} + Reduction_{RP} + Reduction_{DB} + Reduction_{IV}$$

TABLE 24: SMART DRIVING PROGRAM EMISSION REDUCTION BENEFITS

			EIR Alternative			
		No Project	*Proposed Plan*	*Transit Priority Focus*	*Enhanced Network of Communities*	*Environment Equity, and Jobs*
CO_2 Emissions Reductions	2020 Daily Short Tons Reduced	0	-1,452	-1,442	0	-1,428
	2020 Percent Per Capita Reduction from 2005 Baseline	0%	-1.8%	-1.8%	0%	-1.8%
	2035 Daily Short Tons Reduced	0	-1,386	-1,392	0	-1,373

[47] Equation derived from EMFAC 2011.

2035 Percent Per Capita Reduction from 2005 Baseline	0%	-1.5%	-1.6%	0%	-1.6%

Note that the Enhanced Network of Communities Alternative redirects funding allocated for smart driving to local street and road maintenance, and state highway maintenance. Therefore, that alternative has no emissions reduction benefit from smart driving.

Costs

Social Marketing Campaign

Initial advertising costs for the campaign are assumed to be $5 million/year for advertising and program management/development. After four years the campaign spending can be reduced to $2 million/year to remind Bay Area residents to continue practicing the elements of the original campaign. This sums to $56 million in YOE dollars.

In-Vehicle MPG Meters

MTC's $100 rebate could deploy 900,000 in-vehicle devices for $105 million in YOE dollars.

Combined, the total program cost is $161 million in YOE dollars.

Commuter Benefit Ordinance

In 2012, MTC and the Bay Area Air Quality Management District (BAAQMD) successfully supported Senate Bill 1339 which authorizes BAAQMD and MTC to jointly adopt a regional commute benefit ordinance. The purpose of this legislation is to reduce GHG emissions and traffic congestion, and to improve air quality. The BAAQMD and MTC can adopt this new program on or after January 1, 2013. The two agencies are currently developing plans for drafting and implementing this program and will be seeking input from employers as part of the process. The agencies are required to report to the Legislature in 2016 on the results of the program, including the reduction in motor vehicle trips and emissions of greenhouse gases.

The program will require employers with 50 or more full-time employees in the Bay Area to offer their employees incentives to commute to work via modes other than driving alone. Employers would choose to offer one of the following incentives in order to make alternative commute modes more attractive to their employees:

- The opportunity to pay for transit, vanpooling or bicycling expenses with pre-tax dollars, as allowed by federal law (IRS Code Section 132 (f));
- An employer-provided subsidy of $75 per employee per month to pay for transit or a vanpool;
- A free shuttle to the workplace operated by the employer; or
- Any employer-chosen alternative to these options that can be demonstrated to provide an equal or greater benefit in terms of reducing GHG emissions.

ASSUMPTIONS AND METHODOLOGY

The primary impact of commuter benefit programs is a reduction in commuting by single occupancy vehicles (SOVs). Commuters may switch to transit, carpooling, or non-motorized modes. In reality, commuter benefits programs may also generate a few new vehicle trips in shared ride vehicles and may shift trips from one non-SOV mode to another. For the sake of simplicity, this analysis assumes a unilateral shift from SOV to modes that do not generate new vehicle trips: sharing a ride in a vanpool or personal vehicle already on the road, taking transit, or using non-motorized modes.

The legislation has a minimum employer size of 50 employees. Data from Zipcode Business Patterns (ZBP) 2008 was used to estimate the percentage of employers (and employees) to which the legislation would apply. Employer data from ZBP for each zipcode was matched to MTC superdistricts using GIS software. See Figure 30 for a map of MTC's 34 superdistricts.

Some employers already offer the types of benefits described in the legislation. In 2008 the City and County of San Francisco enacted similar legislation. In implementing its ordinance, the City found that 46 percent of employers already offered one of the required benefits prior to implementation of the city's ordinance.[48] Accordingly, it is assumed that 46 percent of employees in the Bay Area would not receive any new benefit as a result of the legislation. This is a conservatively high estimate when applied to areas outside of San Francisco.

Approximately 80 percent of employers in San Francisco who are subject to their ordinance offer only a pre-tax transit benefit. This is the lowest cost option for employers and is therefore assumed to be the compliance path that most employers will choose. To be conservative, we assume that 100 percent of employers choose the pre-tax transit benefit. This option allows employees to purchase transit passes using pre-tax income—a discount of roughly one third for a typical employee.

Empirical research indicates that the long term elasticity of auto trips with respect to transit fares is between 0.15 and 0.3. These figures are synthesized by Litman from several research studies.[49] They represent average effects in a variety of urban contexts thus allowing the elasticity to be applied throughout the Bay Area without a more refined geographical analysis of employer access to transit. To be conservative, the low end of the range is used here. With transit costs reduced by one third, 4.95 percent of drivers would be expected to switch to transit.

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[48] Data supplied by San Francisco Department of Environment

[49] Litman, Todd, "Transit Price Elasticities and Cross-Elasticities," Journal of Public Transportation, vol. 7, No. 2, 2004, p 53

FIGURE 29: SAN FRANCISCO BAY AREA SUPERDISTRICTS

ANALYSIS STEPS

VMT Reduction

1. Match employer data from Zipcode Business Patterns (ZBP) for each zipcode to MTC superdistricts (see Figure 30) using GIS software. Sum the total number of jobs within each superdistrict (SD). A base year of 2008 ZBP data was used for this analysis due to the availability of the data. Since this was a recession year, it is a conservative estimate of the future number of employers subject to the program.

2. Calculate the percentage of jobs within each SD that are located at businesses that meet the 50 employee threshold using data from ZBP. This ranges from 27 to 74 percent with an average of 54 percent of jobs housed within businesses of 50 or more employees.
$$Implementation\ Fraction_{SD} = \sum_{Emp>50} Jobs_{SD} \Big/ \sum Jobs_{SD}$$

3. Use MTC's Travel Model output to calculate daily commute tours by SD and travel mode.

4. Calculate the daily number of SOV commute trips by impacted employers who are *not* already in compliance with the legislation. It is assumed that similar to the results of the program in San Francisco, 46 percent of employers already offer commute benefits. This results in only 54 percent of SOV trips being impacted by implementation of the new program.
$$Impacted\ Trips_{SD} = (Trips_{SD,SOV} \times Implementation\ Fraction_{SD}) \times 0.54$$

5. Calculate the daily number of trips shifted from SOV to transit by the reduction in transit fares. With transit costs reduced by one third, 4.95 percent of impacted trips would be expected to switch to transit.
$$Shifted_{SD} = Impacted\ Trips_{SD} \times 0.0495$$

6. Calculate the daily reduction in VMT from the shifted commute trips and the average trip lengths.
$$Average\ Commute\ Round\ Trip\ Distance = ATD$$
$$VMT_{SD} = Shifted_{SD} \times ATD_{SD,SOV}$$

Emissions Reductions

1. Sum daily shifted trips and use EMFAC2011trip end emission factors to calculate CO_2 reduced. Sum daily VMT reduced and use EMFAC2011 per mile emission factors to calculate CO_2 reduced.
$$Emissions = \sum_{SD} Shifted_{SD} \times Trip\ End\ Rate + \sum_{SD} VMT_{SD} \times Exhaust\ Rate$$

TABLE 25: COMMUTE BENEFIT ORDINANCE EMISSION REDUCTION BENEFIT

		EIR Alternative				
		No Project	*Proposed Plan*	*Transit Priority Focus*	*Enhanced Network of Communities*	*Environment Equity, and Jobs*
CO_2 Emissions Reductions	2020 Daily Short Tons Reduced	-126	-117	-117	-118	-122
	2020 Percent Per Capita Reduction from 2005 Baseline	-0.2%	-0.1%	-0.1%	-0.1%	-0.1%
	2035 Daily Short Tons Reduced	-264	-233	-237	-244	-246
	2035 Percent Per Capita Reduction from 2005 Baseline	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%

Cost

While it is assumed that all employers subject to the legislation will comply with it, MTC and the BAAQMD are committed to providing outreach and assistance to local employers through their existing employer outreach programs.

Vanpools/Employer Shuttles

Vanpool

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 start-up fees, up to $100/year to encourage continued participation when a passenger is lost, free bridge tolls, and various other incentives. With these basic incentives there is an operational vanpool fleet in the Bay Area. However, there has been a significant decrease in the number of vans in recent years. The current fleet numbers 515 vans. This translates to over 5,500 residents commuting to work in vanpools daily.

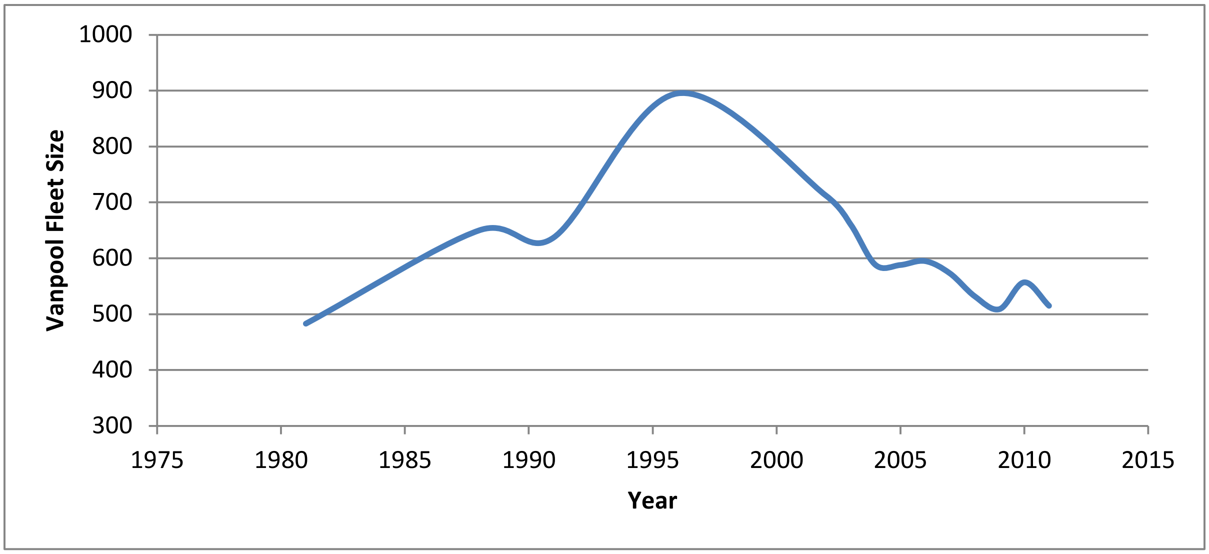


FIGURE 30: VANPOOL FLEET SIZE

Shuttles

In addition to these traditional vanpools, there has been an explosive growth in the number of employer provided shuttles in the Bay Area. These shuttles are used as a recruiting tool and they allow for increased worker productivity due to the onboard wireless internet, thus turning commute time into productive time. Rough estimates indicate that the big technology company shuttles that operate between San Francisco and Silicon Valley transport close to 17,500 people per workday.[50] The Google shuttle alone carried about 4,500 employees to work every day in 2011 and they were anticipating that the program would grow to 6,000 workers per day in 2012 and more beyond that.[51] Google's shuttle system began as a vanpool in 2006 and rapidly grew into the current system.[52] Prior to the SB 375 GHG emissions baseline year there were very few employer provided shuttles in the region. For purposes of this analysis there are assumed to have been no shuttles prior to 2005.

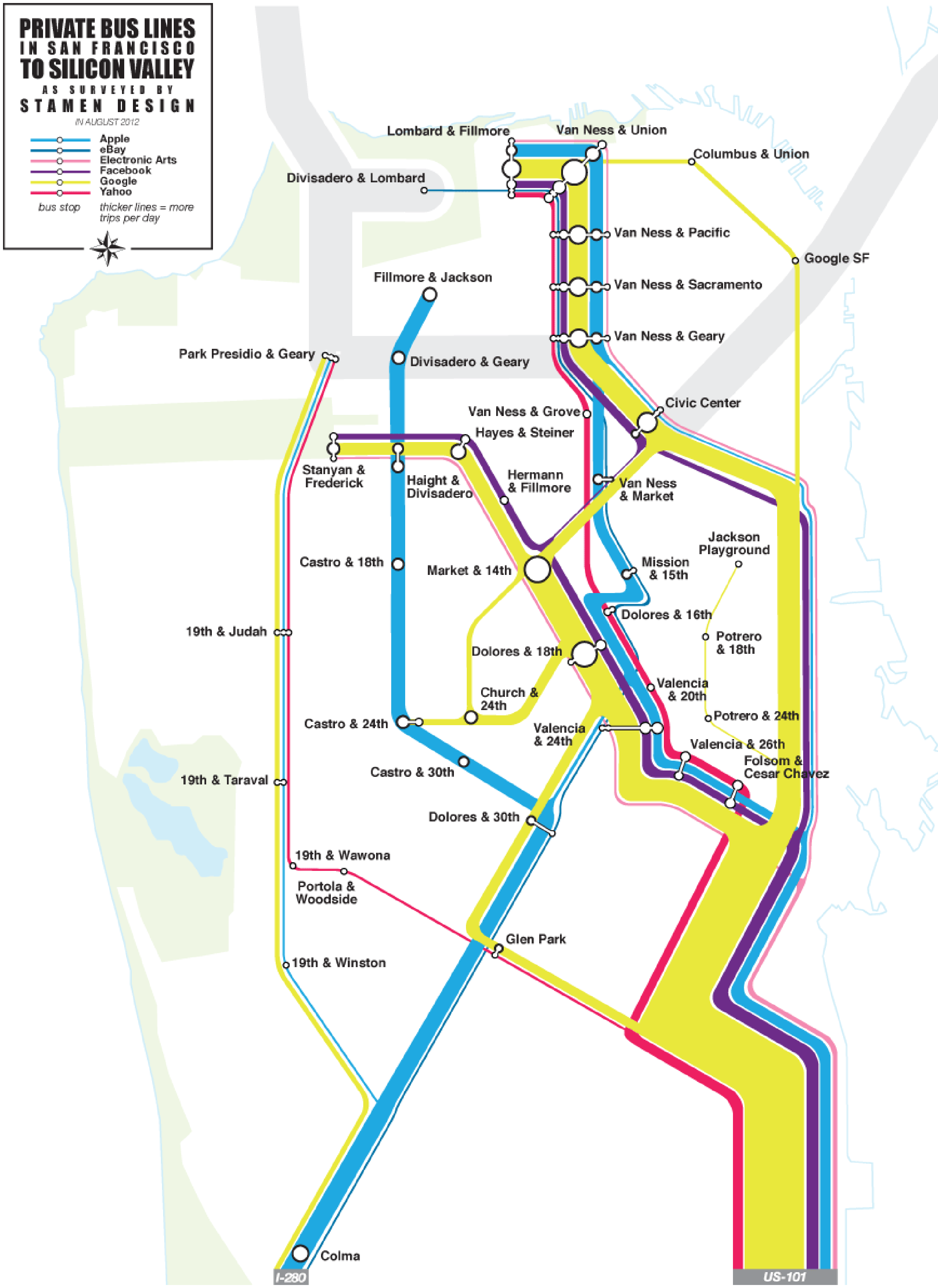
The figure on the following page takes the detailed shuttle routes in San Francisco and simplifies it into a subway style map to communicate relative shuttle volumes. Although the map only shows data for shuttles running from San Francisco to Silicon Valley, there are private shuttles running through all parts on the Bay Area including intra-San Francisco, the East Bay, the Peninsula, around San Jose, and from

[50] Based on Stamen's estimate that San Francisco shuttles carry approximately equal to 35% of Caltrain ridership levels (http://stamen.com/zero1/). Obtaining shuttle ridership levels is extremely difficult due to the confidential nature of the information since businesses use these shuttles as a recruiting tool. In the month prior to Stamen releasing their work, Caltrain reported ridership levels of 50,000 passengers per weekday. http://www.caltrain.com/Page1731.aspx

[51] Google Green, Accessed March 13, 2013. http://www.google.com/green/efficiency/oncampus/

[52] Ibid.

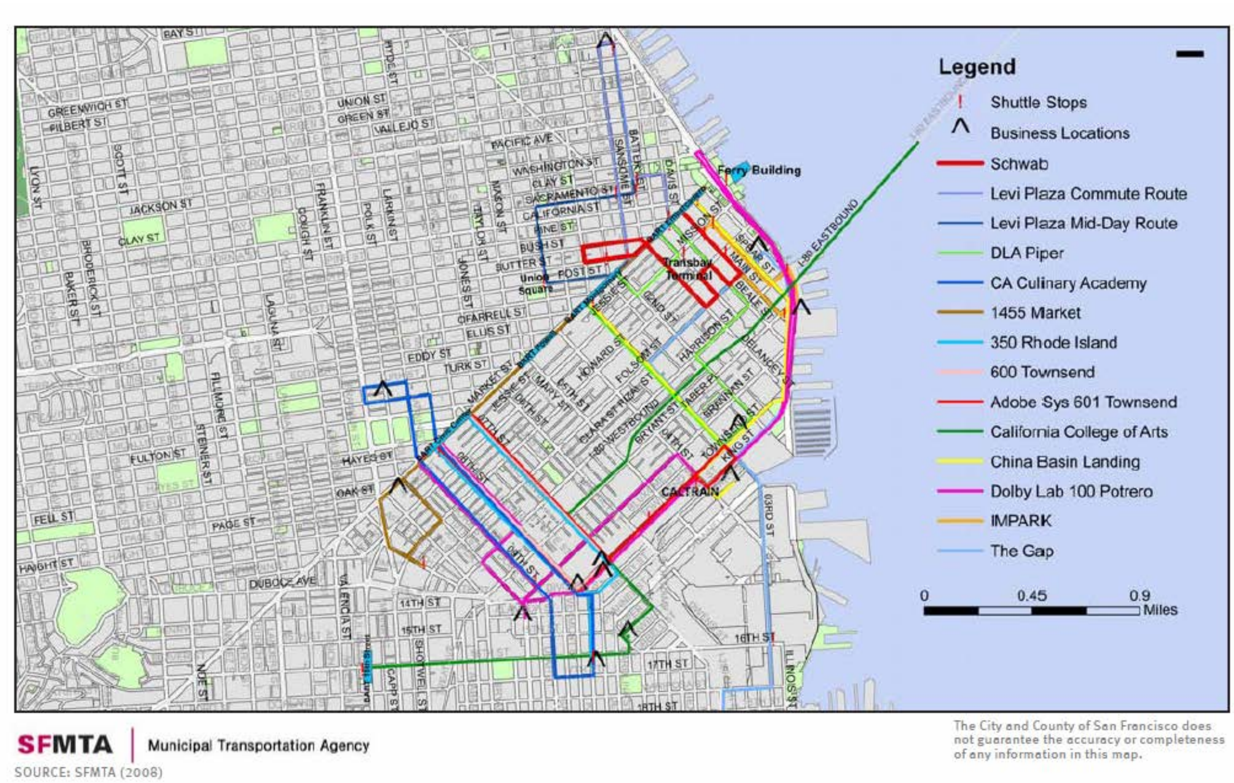
BART and Caltrain stations to corporate campuses. These shuttles are not represented in MTC's travel model and thus must be accounted for in this off-model analysis.



Stamen Design. The City from the Valley 2012. http://stamen.com/zero1/

FIGURE 31: SAN FRANCISCO TO SILICON VALLEY EMPLOYER OPERATED SHUTTLES

For a representation of the shuttle routes operating in the South of Market neighborhood of San Francisco see the following map. The high density of the shuttle routes illustrates the popularity of these offerings.



Source: San Francisco County Transportation Authority, Strategic Analysis Report: The Role of Shuttle Service in San Francisco's Transportation System. June 2011. http://www.sfcta.org/sites/default/files/content/Planning/Shuttles/Final_SAR_08-09_2_Shuttles_062811.pdf

FIGURE 32: SOUTH OF MARKET EMPLOYER SHUTTLE ROUTES

ASSUMPTIONS AND METHODOLOGY

Vanpools

MTC will implement a $400/month/van subsidy for as long as the vanpool operates and meets the minimum usage requirements. This is the same incentive that SANDAG offers in the San Diego region. They have seen strong growth in their program since its inception in 1995. Currently vanpool rentals cost approximately $1,300[53] to rent and operate per month. The $400 per month would reduce these costs by 31 percent.

MTC assumes this incentive will significantly increase the vanpool fleet, at a minimum resulting in a doubling of the fleet. This equates to 1,030 vanpools, slightly more than the 1996 peak of 900 vans. It is

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[53] Based on staff conversations with vanpool users.

assumed that the average of 10.8 passengers per vanpool and roundtrip distance of 116 miles remains constant over time. In order to account for the emissions from the vanpool van itself, the calculations only account for 9.8 passengers in the van. Reducing the vanpool size is a simplified proxy for the emissions from the shared van.

The population that shifts to vanpools is anticipated to be consistent with the general population's commute mode share. Information on this mode split for the Proposed Plan is found in Table 26. For the other EIR Alternatives the mode shares vary by ±3 percent. Emissions reduced from a commuter switching from a single occupancy vehicle (SOV) are assumed to be 100 percent. Emissions reduced from a commuter switching from a two person carpool are assumed to be 50 percent. Emissions reduced from a commuter switching from a 3+ person carpool are assumed to be 33 percent.

Since the baseline year for the SB 375 GHG 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 accounted for.

TABLE 26: PROPOSED PLAN COMMUTE MODE SHARE

Commute Mode	***2020***	***2035***
Single Occupancy Vehicle	67%	63%
Carpool (2 People)	10%	10%
Carpool (3+ People)	5%	5%
All Other Modes	18%	22%

The "all other modes" category includes walking, biking, and transit use. These modes are assumed to be non-emitting and therefore no emissions benefits (or disbenefits) are assessed for shifts from these modes to vanpools or shuttles.

Employer Shuttles

It is assumed that increases in the shuttle fleet from this point forward will be caused by companies meeting the requirements of the Commuter Benefit Ordinance (CBO). However, in the CBO analysis it is assumed that 46 percent of employers are already in compliance with the program. These commuters are not included in the CBO analysis because the analysis is based on increased transit use and that level of transit use is accounted for in Travel Model One. But employer operated shuttles are not accounted for in *Travel Model One*. For this reason, the existing fleet of employer shuttles which are not accounted for in the *Travel Model One* nor the CBO analysis are included here.

To be conservative, this analysis will assume that the 17,500 daily employer operated shuttle riders from San Francisco to the Silicon Valley account for all employer operated shuttle riders in the Bay Area.

It is assumed that the shuttles carry an average of 30 passengers[54] and that the average round trip commute on a shuttle is 40 miles[55]. The same as for vanpools, it is assumed that if there was not a shuttle available then the passengers commute mode split would mirror that of the general population. This is supported by the San Francisco County's survey of shuttle riders which indicated that 63 percent of shuttle riders would have otherwise driven alone to work[56].

The shuttles have their own emission impacts as well. It is assumed that the shuttles mirror the average emissions of urban buses. This is likely an overestimate of the emissions since the shuttle buses are generally smaller and the employers who have taken a proactive approach to alternative transportation are generally striving to use the cleanest vehicles available. The exhaust emission rate extracted from EMFAC 2011 and used for 2020 shuttles is 2,311.3 grams/mile. The 2035 exhaust emission rate is 2,151.7 grams/mile.

ANALYSIS STEPS

Vanpool

1. Calculate the daily VMT traveled in vanpools less the vanpool driver mileage. As stated in the assumptions, vanpool members are anticipated to mirror the general population commute mode split prior to joining the vanpool. Only the *increase* in the vanpool fleet is used for this analysis. It is assumed that average vanpool commute distance and average riders per van are consistent over time.

$$Future\ Vanpool\ Fleet = FF$$

$$Existing\ Vanpool\ Fleet = EF$$

$$Average\ Round\ Trip\ Commute\ Length = RT$$

$$Single\ Occupancy\ Vehicle\ Mode\ Share = SOV$$

[54] SFCTA Strategic Analysis Report (SAR) 08/09-2. The Role of Shuttle Services in San Francisco's Transportation System. http://www.sfcta.org/sites/default/files/content/Planning/Shuttles/Final_SAR_08-09_2_Shuttles_062811.pdf Most shuttles have a capacity of 25 passengers but the large employers operated shuttles that seat 50 to 70 passengers. A average capacity of 30 passengers per shuttle seemed appropriate.

[55] Many shuttles operate from BART or Caltrain to employers offices. For this analysis the average round trip commute length includes a passengers travel on transit since that is part of their low emission commute.

[56] SFCTA Strategic Analysis Report (SAR) 08/09-2. The Role of Shuttle Services in San Francisco's Transportation System. http://www.sfcta.org/sites/default/files/content/Planning/Shuttles/Final_SAR_08-09_2_Shuttles_062811.pdf

$$Two\ Person\ Carpool\ Mode\ Share = SCarpool$$

$$Three\ Plus\ Person\ Carpool\ Mode\ Share = LCarpool$$

$$VMT = ((FF - EF) \times (Riders - 1) \times RT) \times (SOV + SCarpool \times 0.5 + LCarpool \times 0.33)$$

2. Calculate the trips per day eliminated by the vanpool riders.

$$Trips = ((FF - EF) \times (Riders - 1)) \times (SOV + SCarpool \times 0.5 + LCarpool \times 0.33)$$

3. Use EMFAC 2011 emission factor rates to calculate the emissions reduced from the vanpools.

$$Emissions = VMT \times Exhaust\ Rate + Trips \times Trip\ End\ Rate$$

Shuttles

1. Calculate shuttle passenger VMT eliminated.

$$VMT = Passengers \times RT \times (SOV + SCarpool \times 0.5 + LCarpool \times 0.33)$$

2. Calculate the vehicle trips reduced by the shuttle passengers.

$$Trips = Passengers \times (SOV + SCarpool \times 0.5 + LCarpool \times 0.33)$$

3. Calculate the minimum number of shuttle trips required to transport the shuttle riders.

$$Shuttle\ Trips = \frac{Passengers}{Shuttle\ Capacity}$$

4. Calculate the minimum shuttle VMT to serve the passengers.

$$Shuttle\ VMT = Shuttle\ Trips \times RT$$

5. Calculate the shuttle emissions using the urban bus (UB) EMFAC 2011 Emissions Factors.

$$Shuttle\ Emissions = Shuttle\ VMT \times UB\ Rate$$

6. Calculate the shuttle passenger emissions reductions.

$$Passenger\ Emissions = VMT \times Exhaust\ Rate + Trips \times Trip\ End\ Rate$$

7. Subtract the shuttle emissions from the passenger emissions to obtain the net emissions reduced.

$$Net\ Emissions = Passenger\ Emissions - Shuttle\ Emissions$$

TABLE 27: VANPOOL INCENTIVE/EMPLOYER SHUTTLE EMISSION REDUCTION BENEFIT

		EIR Alternative				
		No Project	*Proposed Plan*	*Transit Priority Focus*	*Enhanced Network of Communities*	*Environment Equity, and Jobs*
CO_2 Emissions Reductions	2020 Daily Short Tons Reduced	-176	-230	-231	-230	-227
	2020 Percent Per Capita Reduction from 2005 Baseline	-0.2%	-0.3%	-0.3%	-0.3%	-0.3%
	2035 Daily Short Tons Reduced	-180	-355	-362	-353	-351
	2035 Percent Per Capita Reduction from 2005 Baseline	-0.2%	-0.4%	-0.4%	-0.4%	-0.4%

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Metropolitan Transportation Commission

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Association of Bay Area Governments

Management Staff

Ezra Rapport
Executive Director

Patricia Jones
Assistant Executive Director

Kenneth K. Moy
Legal Counsel

Miriam Chion
Planning and Research Director

Association of Bay Area Governments

Joseph P. Bort MetroCenter
101 Eighth Street
Oakland, CA 94607-4707

510.464.7900 PHONE
info@abag.ca.gov EMAIL
www.abag.ca.gov WEB

Metropolitan Transportation Commission

Joseph P. Bort MetroCenter
101 Eighth Street
Oakland, CA 94607-4700

510.817.5700 PHONE
510.817.5769 TDD/TTY
info@mtc.ca.gov EMAIL
www.mtc.ca.gov WEB