Research Report – UCD-ITS-RR-14-10

California Beyond SB 375: Evaluating the Impact of Proposed Land Use and Transportation Plans on Future Travel Patterns and Interregional Travel Behavior

August 2014

Giovanni Circella
Andrew McFadden
Farzad Alemi

Institute of Transportation Studies ◦ University of California, Davis
1605 Tilia Street ◦ Davis, California 95616
PHONE (530) 752-6548 ◦ FAX (530) 752-6572
www.its.ucdavis.edu

University of California Transportation Center
UCTC-FR-2014-06

California Beyond SB 375: Evaluating the Impact of Proposed Land Use and Transportation Plans on Future Travel Patterns and Interregional Travel Behavior

Giovanni Circella, Andrew McFadden,
and Farzad Alemi
UC Davis
August 2014

DISCLAIMER

California Beyond SB 375: Evaluating the Impact of Proposed Land Use and Transportation Plans on Future Travel Patterns and Interregional Travel Behavior

Report to the
University of California Transportation Center

By

Dr. Giovanni Circella

Andrew McFadden

And

Farzad Alemi

Institute of Transportation Studies
University of California, Davis
One Shields Avenue
Davis, CA 95616

December 2013

DISCLAIMER

Table of Contents

List of Tables

List of Figures

EXECUTIVE SUMMARY

This report summarizes the findings from the project *After SB375: Using Statewide Activity-Based Modeling to Assess the Impact of Sustainable Community Strategies on Regional and Interregional Travel Behavior*, funded by the University of California Transportation Center (UCTC). The project investigates the effects of some of the proposed land use and transportation policies that are currently being developed by Metropolitan Planning Organizations (MPOs) in California, as an effect of recent environmental regulations, on regional and interregional trips, personal and total vehicle miles traveled (VMT), modal split, and VMT per capita.

In 2010, transportation accounted for over one third of greenhouse gas emissions in California (California Air Resource Board, 2013). Additional externalities of congestion, deterioration of local air and water quality, injuries and death, and habitat destruction weigh heavily on the daily lives of Californians. With an expected population growth of 24% from 2010 to 2035, according to the forecasts from the California Department of Finance, these problems will likely worsen if proper actions are not undertaken to reduce transportation externalities.

In response to these generated pressures, Assembly Bill 32 (AB32), the Global Warming Solution Act of 2006, was passed by the California legislature and signed by Governor Schwarzenegger. According to AB 32, the State of California is required to reduce GHG emissions to 1990 levels by 2020. The Governor's Executive Order (S-3-05) targets an additional 80% reduction in GHG emissions below 1990 levels by 2050. To achieve these goals, several policy packages have been passed since 2006. Lower carbon fuel, higher fuel efficiency, and a zero emission vehicle mandate have targeted transportation technology. Yet, despite advances in these areas, CO2 emissions from the transportation sector will continue to rise if travel demand (in particular, the use of single-occupancy vehicles) and the distances between land uses do not decrease. As SB 375 Section 1 article c states, "… *Without significant changes in land use and transportation policy, California will not be able to achieve the goals of AB 32*."

To pursue these goals, Senate Bill 375 (SB375), the Sustainable Communities and Climate Protection Act, in 2008 introduced the requirement for metropolitan planning organizations (MPOs) to create Sustainable Community Strategies (SCSs) in order to meet established GHG emission targets for 2020 and 2035. These regional planning policy packages are designed to meet the transportation and housing needs of the regions' population while ensuring the long term environmental sustainability of California's communities. Measures of mobility, maintenance, safety, and equity are some of the specific planning elements required by the plan. Each MPO is also required to identify the general location of land uses, areas of housing, resource areas, and a transportation network to serve the needs of current and future residents. To tie these elements together, an action plan that describes the specific programs and actions needed to achieve the policy goals is also required by the law.

In this study we use the California Statewide Travel Demand Model (CSTDM) to test the impact of select changes in land use and transportation planning in California. The CSTDM modeling framework was developed for purposes of travel demand modeling in the State of California, and is applied in this study to test two main scenarios for the year 2035:

I. A *control* ("business as usual") scenario, under assumptions of current growth and economic development established by former Regional Transportation Plans (RTPs), and
II. A modified land use and transportation scenario inspired by the development of the most recent RTPs and SCSs from the local MPOs (where these updated plans are already available).

The rationale behind this study lies in the advantages offered by the application of the CSTDM as an advanced statewide travel demand model to evaluate the impact of land use and transportation policies developed at regional (MPO) levels in California. Considerable experience exists on the evaluation of the impact of transportation and planning policies on travel behavior through the application of regional models and/or studies that focused on specific interregional transportation corridors. However, the application of the CSTDM framework to test the impact of some of these proposed policies in this study provides three main advantages, if compared to other studies that have tested the effects of policies with MPO models that operate at regional scales:

1. it allows modeling the effects of the proposed policies using consistent modeling assumptions for the entire State of California, overcoming possible differences in the computation of modeling results across regions;
2. it provides for a broader evaluation of policies by simulating both regional (short distance) and interregional/long-distance components of travel;
3. the study provides information on the marginal modifications introduced in transportation patterns by the adoption of the recent SCS plans, compared to the previous trends resulting from previous policy and investment plans. This information can be useful to support the development of improved policies in areas of the state without draft or published SCSs.

At the same time, using a statewide modeling framework to evaluate the impact of policies that might include local details that cannot be properly modeled in a large scale modeling framework presents some limitations, mainly due to the scale and assumptions of this modeling tool. For these reasons, this study does not substitute, but rather complements the use of regional models to evaluate these policies. It also provides useful information for the community of researchers and policy-makers on the overall impact of the proposed policies and suggests possible ways to further increase their success, in particular in those areas where final SCS documents have not been developed and/or approved yet.

The CSTDM framework addresses all major components of long and short distance travel demand using an activity-based micro-simulation approach during four time periods in an average weekday. It integrates five main travel demand sub-models:

1. Short Distance Personal Travel Model (SDPTM)
2. Short Distance Commercial Vehicle Model (SDCVM)
3. Long Distance Personal Travel Model (LDPTM)
4. Long Distance Commercial Vehicle Model (LDCVM)
5. External Trip Model (ETM).

The modeling framework assigns vehicle traffic generated by all five sub-models to the road network in the assignment step. The use of public transportation for all rail-based and bus rapid transit (BRT) lines is simulated through the explicit coding of all public transit lines and services. Local bus services are coded using a synthetic approach. This latter method is based on the estimation of econometric models that represent the local transit attributes (in-vehicle travel time and out-of-vehicle waiting and transfer time) as functions of other variables used in the modeling framework, including HOV travel time, population and employment densities, and the bus operator's level of service (LOS).

In this research project, we consolidate information from the RTPs/SCSs from local MPOs and a variety of other sources into the creation of policy scenarios that are tested with the CSTDM travel demand model. The research focused on general land use and transit investments promoted by MPOs in California. Other policies, such as electric vehicle adoption incentives, microscale land use projects or cordon pricing were not included in the analyses. In this study, new land use forecasts from each MPO are incorporated into the creation of the SCS-inspired modeling scenario. New transit lines, line extensions, and operational improvements (e.g. shortened headways) are obtained from each MPO with a published SCS and are also included into this scenario. For areas yet to establish their SCS, figures from the California Department of Transportation and Department of Finance are used to update regional employment and population totals, respectively. Additionally, some strategies seen in published SCSs are applied to these regions to shift future growth towards denser urban areas and improve the level of service of local public transportation.

In this project, two additional partial scenarios are also created, in order to test in the modeling framework the partial contributions, in isolation, of respectively the proposed changes introduced in land use (*land use* scenario) and the proposed investments in public transportation (*transit* scenario). The results from these partial scenarios are compared to the overall results of the SCS-inspired modeling scenario and of the control (business as usual) scenario.

The use of the CSTDM to model the proposed scenarios enables an investigation of how these proposed policies can contribute to reduce the environmental externalities from transportation and reach the goals established by AB 32 and SB 375. The results from the SCS-inspired scenario shows that the combination of the proposed land use and transportation policies are expected to reduce short distance personal VMT in 2035, on average, 2.8% in the entire State, if compared to current trends that would be obtained if these policies had not been developed. Large variations in these results are seen between regions with forecasted VMT reductions ranging between 0.6% in San Diego and 9.7% in the MTC region (San Francisco Bay Area). Increases in transit mode share are also observed for each MPO with a published SCS. In general, higher increases in the percentage of population served by transit and in the urban density in transit corridors are associated with more environmentally-benign travel outcomes.

The results from the application of the modeling framework to the partial scenarios that simulate land use and transit policies separately indicate that land use changes are responsible for the majority of VMT reductions in most regions of California. Yet, again, large variation is observed in these figures depending on the policy focus and effectiveness in each region. In addition, important synergies are found in many cases, where reductions made from the combination of transit and land use policies were greater than the sum of the effects associated with each partial scenario modeled in isolation. This confirms the importance of coordinating land use changes with transportation planning, and in particular with public transportation investments, which is at the basis of the legislative instrument that instituted the Sustainable Community Strategies.

When the results from this study are compared with local MPO forecasts, it emerges that the modeling results obtained from the application of the CSTDM model usually appear to be more conservative than the results published in the RTP/SCS documents from local MPOs. Changes in VMT per capita estimates in 2035 (from the Control "business as usual" scenario to the SCS scenario) in the state's four largest MPOs often deviate largely from the MPO estimates. This might be, however, partially due to differences in modeling assumptions across regions, differences in the estimates reported by MPO documents as well as to several smaller scale policy changes that could not be fully simulated with the statewide model.

Results from this study indicate that changes in land use and transit investment in the published Sustainable Community Strategies will contribute to lower VMT and increase non-motorized travel in short distance passenger travel. Integrated transportation-land use plans hold promise for more sustainable travel in the future; in particular, synergistic effects from coordinated land use and transportation policies shown in this study can improve outcomes above the individual effects of the policies. However, several uncertainties are associated with the expected outcomes from these policies, and it is not entirely clear whether these policies will be actually able to achieve the proposed targets of reduction in transportation-related emissions. For instance, the correct implementation of the SCSs requires strict cooperation and action alignment from local and regional governments, which to date still appear unclear. At the time this report is written, it is still largely unknown to what extent many land use changes designed by regional MPOs will be actually implemented at the local level, also considering political, fiscal, and other constraints faced by local administrations and planning organizations.

1. Introduction

In 2010, on-road transportation accounted for an estimated 35.4% of GHG emissions in California (California Air Resource Board, 2013). Severe traffic congestion plagues many urban areas in California, with the San Francisco Bay and Los Angeles region constantly listed among the nation top five most congested cities (Schrank et al., 2012). This massive cost of travel in America's most populous state currently weighs heavily on its citizens and the environment. In years to come, population growth and economic development will only increase transportation demand, whereby generating additional pressure on Californian's lives as well as the environment inside and out of the state. In response to these generated pressures, AB32 (Global Warming Solution Act of 2006) was passed by the California legislature and signed by Governor Schwarzenegger. According to this legislation, the State of California is required to reduce GHG emission to 1990 levels by 2020. The Governor's Executive Order (S-3-05) targets an additional 80% reduction in GHG emissions below 1990 levels by 2050. To achieve these goals, several policy instruments have been designed since 2006. The Sustainable Communities and Climate Protection Act (SB 375) passed in 2008 requires metropolitan planning organizations (MPOs) to create Sustainable Community Strategies in order to meet GHG emission established targets for 2020 and 2035. These policies are designed to achieve significant reductions in greenhouse gas (GHG) emissions from land use and transportation, as part of a comprehensive plan to cut GHG emissions from 2005 to 2035. This regulation fits in an overall plan pursued by California to promote voluntary reductions in pollutant emissions, and increase environmental sustainability and quality of life in the state.

Transportation GHG reductions are expected to be attained through (a) increasing vehicle efficiency, (b) decreasing transportation demand, and (c) shifting transportation demand to low GHG emitting and more environmental sustainable transportation modes. This three-legged approach to sustainable reform is the genesis of the landmark legislation set forth by the Assembly Bill 32. Accordingly, SB 375 Section 1, article c, states that:
"Greenhouse gas emissions from automobiles and light trucks can be substantially reduced by new vehicle technology and by the increased use of low carbon fuel. However, even taking these measures into account, it will be necessary to achieve significant additional greenhouse gas reductions from changed land use patterns and improved transportation. Without improved land use and transportation policy, California will not be able to achieve the goals of AB 32."
Similarly, Section 2 of the bill outlines the use of planning models and analytical techniques to assess the effect of new policy decisions. Specifically, emphasis in the regulation is placed on improving the fidelity of travel demand models in order to assess the broader interaction of policies for fulfilling environmental sustainability targets.

As part of the implementation of these regulations, the California Air Resources Board (CARB) has set MPO-specific targets for GHG reductions. Local MPOs are required to develop comprehensive plans for land use and transportation development, the *Sustainable Community Strategies* (SCS), to be integrated in their Regional Transportation Plans (RTP). The objective of a region's RTP/SCS is to meet the transportation and housing needs of its population while ensuring an appropriate reduction in the environmental impact from transportation to obtain long term environmental sustainability and livability in California's communities.

The California Air Resources Board has established stricter guidelines on travel demand models, as well as model input oversight, in order to ensure that the impact of the RTPs/SCSs are properly evaluated and that the produced forecasts fulfill common standards throughout the state. Though this process has attracted attention on the development of sustainable policies, and has prompted considerable modeling improvements, there is still a rather large disparity between the modeling processes adopted at different MPOs throughout the state. Geographically larger, and better funded, MPOs have usually implemented increasingly complex travel models that use more comprehensive assumptions on travel behavior and detailed simulation of policy outputs. In contrast, smaller MPOs often rely on more basic and limited modeling tools, which account only for the main features of the transportation system, and support more limited evaluation of policy packages. Large variation exists in the assumptions, level of details and scales used in the travel demand models throughout the state. This makes it considerably more difficult to evaluate all policies using the same metrics throughout all regions. In addition, regional models are not able to properly assess the effects of policies on interregional travel, which involves trips across the boundaries between the regions that are modeled.

The Sustainable Community Strategies are expected to reshape the future development of local communities in California and help achieve the goals of reduced GHG emissions and increased environmental sustainability in the state. However, a large part of their potential success depends on the way these policies will be implemented. The development of these strategies is a delicate process, which involves many considerations in terms of environmental, social and economic impacts of the proposed policy tools and plans. Eliot Rose (2011) of the Center for Resource Efficient Communities points to 4 key elements affecting the success of SB 375 at reducing GHG emissions: MPOs' ability to identify land use opportunities, sufficient transportation funding, capable travel models to test policies, and if incentives for implementation are adequate. To date, the development of SCSs has generally not been coupled with additional economic tools (e.g. pricing, gas taxes or incentive programs). There are a few notable exceptions to this trend, however, like the congestion pricing schemes proposed by MTC in downtown San Francisco and Treasure Island. Generally as a result of limited pricing policies these policy packages might produce results that are below expectations (Heres-Del-Valle and Niemeier, 2011; Chatman, 2011). Still, as many regions in California have yet to adopt their SCSs, a proper assessment of the expected results of these policy tools cannot be fully carried out to date.

In this study we use the California Statewide Travel Demand Model (CSTDM) as a tool to test the impact of some of the proposed changes in land use and transportation in California. The CSTDM modeling framework was developed for purposes of travel demand modeling in the State of California. Its large scale and the ability to model intrazonal to interregional transportation effects coupled with the uniformity it uses to predict travel demand in all regions provides useful advantages in its application to policy evaluation. In this study, the CSTDM modeling framework is applied for the year 2035 to test two main scenarios:

I. A *control* (business as usual) scenario, under assumptions of current growth and economic development established by former RTPs, and
II. A modified land use and transportation scenario inspired by the development of the most recent RTPs and SCSs from the local MPOs (where these updated plans are already available).

Additional scenarios were tested as part of the modeling project, to evaluate the impact of specific combination of policies and intermediate scenarios. Most significantly for this project, two partial scenarios were developed on the basis of the SCS-inspired scenario. These two scenarios respectively simulated the impact, in isolation, of the proposed land use changes and proposed investments in public transportation. The two scenarios are useful to analyze the relative contributions to the achievement of the environmental targets established by California laws of the two subsets of policies contained in the recent RTPs/SCSs. The comparison between the results from these scenarios and the SCS-inspired scenario are also useful for the assessment of eventual synergies arising from the contemporaneous implementation of multiple policy packages.

The study is useful to test the potential impact of some of the proposed transportation and land use policies in 2035 in the entire state of California. The study does not attempt to create an official evaluation of the SCS programs, given several limitations to the application of the CSTDM modeling framework to simulate the impact of these policies in the current project, including:

- The large interregional scale and the purpose of the statewide model that is used (which does not allow detailed simulation of the effects of the proposed policies on travel behavior at the local level);
- The limited representation of public transportation services in the CSTDM, which are represented through a hybrid methodology (see section 4 of this report for more details), which is well suited for the inclusion of all relevant public transportation services in a statewide model, but does not allow for detailed simulation of access/egress to local public transportation at the neighborhood/block level;
- The limited availability of data on these policy packages, to date, as the updated SCS plans are not yet available for many regions in the State.

However, its application is useful to provide information that could not be tested with regional travel demand models. In particular, it allows:

- The possibility to simulate the impact of transportation and land use policies developed in the most recent RTP/SCS plans on both regional and interregional (crossing borders between MPOs) travel flows;
- The ability to simulate the effects of the proposed policies using a standardized modeling framework, which uses the same methodological framework, assumptions, types of input data and level of spatial details for all regions in the State, thus overcoming the differences currently existing among travel demand models and modeling studies in different regions;
- The capacity to use the expertise developed in the analysis of the SCS inspired policies, including smart growth land use and improved access to transit, to support the development of model-based policies in areas of the state without draft or published SCSs.

This study is therefore intended to complement, and not replace, studies developed with more detailed regional models in the state. The study provides useful insights into the potential impact of these policies, and it contributes to the debate in the scientific and policy-making community on the development of these policy packages and strategies. It also investigates these policies' potential impact to increase environmental sustainability, and livability of local communities in

California, and reach the established goals of reduction of the environmental impacts (in particular, pollutant emissions) from transportation. The results support the discussion on how to eventual improve some of the proposed policies, in order to fulfill the proposed environmental goals.

2. Literature Review

VMT reduction is considered an important objective in policy development to achieve GHG emissions reductions. However, some authors have indicated that it might be an indirect and costly method to achieve these targets (Moore et al. 2010). These advocates suggest using direct methods like fuel standards and operational improvements to curb GHG production, while preserving the freedom and convenience associated with automobile travel. However, according to recent research results, technological advances in the reduction of the carbon content of fuel and increases in fuel economy will not be able per se to achieve reduction targets. In this case, CO2 emissions from the transportation sector will continue to rise due to growth in demand for driving and the millage people need to travel to access to their destinations. This indicates the exigency of more aggressive measures to reduce demands for driving. Figure 2-1 shows the projected growth of CO2 even under stringent vehicles and fuel standards (U.S. Energy Information Administration, 2007)

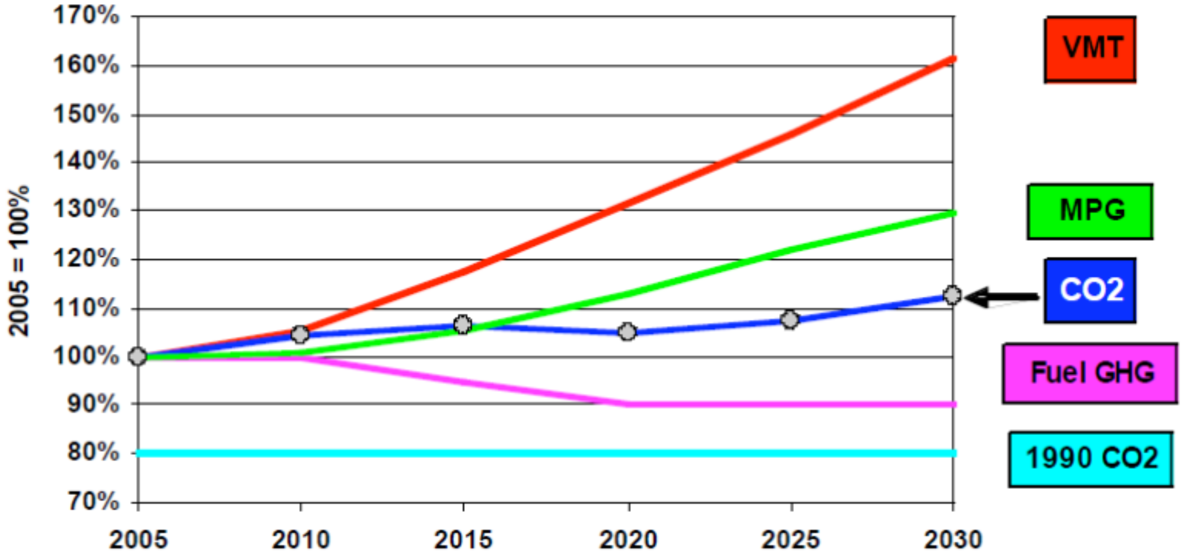

Figure 2-1: Projected CO2 emissions from light duty vehicles under stringent vehicle and fuel standards

In the short term policies to change travel behavior remain a powerful tool to curb the growth in CO2 from transportation. More importantly, in the long term, changing the way we travel is evidently required even if zero emission vehicles become more common and will account for larger shares of the vehicle fleet.

Considerable experience exists on the evaluation of the impact of transportation and planning policies on travel behavior. Particularly important to this evaluation are the goals and metrics that are used. As this research explores the effectiveness of policies to influence how sustainable our travel is and how livable our surroundings are, livability and sustainability are our primary areas of emphasis. According to the U.S. Department of Transportation, the six primary objectives defining livability can be summarized as follows (USDOT, 2009):

- Transportation Choices
- Equitable and affordable housing

- Increase economic competitiveness
- Support existing communities
- Coordinate policies and remove barriers to collaboration
- Value Communities.

Different definitions of sustainability exist though. Generally, sustainability entails meeting the needs of today without sacrificing for tomorrow (from an environmental/ecological perspective). However, various different applications to transportation have been proposed as well. For example, SCAG's RTP from 2008 focused on transportation system sustainability by defining "sustainability" as the cost per capita to maintain transportation system performance (pg. 171), thus focusing on the financial/economic meaning of the term.

Jiangping Zhou (2012) provides a review of the various uses and definitions of sustainability. In the remainder of this document, unless otherwise specified, we will usually refer to the definition of environmental sustainability when discussing the objectives of the policies that are tested as part of this research.

In the following brief, and necessarily non-comprehensive, literature review, we discuss some previous studies that have investigated the expected impact of land use policies and transportation system modifications on travel behavior. We will first focus on non-travel-demand-modeling-based studies. Particular emphasis is placed on the coverage of some topics including modal split, travel behavior, and land use impacts. We will then turn to summarize previous approaches from the literature to evaluate policies through the application of travel demand models.

2.1 Non Model-Based Land Use Transportation Policy Analysis

The topic of the interactions between land use and transportation has been heavily studied over the past two decades, in particular with a focus on the relationships involving built environment variables like density, extension of the road network, and distance to transit. Many of these studies have important implications in terms of the expected impact of related transportation policies. Early research by Newman and Kenworthy (1989) explored the relationship between travel cost and density around the world. This study concluded that, at an aggregate, lower density areas are associated with increased car dependence and higher energy consumption for transportation. However, this milestone study was partially criticized by several sources for the failure to include a multivariate analysis to address other variables affecting the land use-transportation relationship (Mindali et al., 2004). Other research by Boarnet and Crane (2001) used data from Southern California to determine that land use characteristics affect trip prices through speed and distance, and that, in turn, affects trip generation and mode choice.

In the study by Ewing et al. (2003) the 83 largest metropolitan areas in United States were ranked based on a sprawl index, including density, diversity, connectivity and strength of activity center, while controlling for socio-demographic variables. The result indicated that a substantial increase (2 standard deviations) in a defined density factor is associated with 10.75 less daily vehicle miles per capita. This difference can roughly be described as moving from Washington D.C. to San Francisco. Moreover, a substantial increase in centeredness, defined as a measure of clustering, results in 2.3 less daily vehicle miles per capita (a quarter of which related to density). A substantial increase in centeredness like this can be seen moving from Los Angeles to Portland, OR. A summary of the study's factors and their effect on transportation outcomes is shown in Table 2-1 below.

Table 2-1: Transportation Outcomes versus Sprawl Factors (Source: Ewing et al., 2003)

	Transportation Outcomes							
	Vehicles per Household	***Transit Share of WorkTrips***	***Walk Share of WorkTrips***	***Mean Travel Time to Work***	***Annual Delay per Capita***	***VMT per Capita***	***Fatalities per 10,0000 Population***	***Peak Ozone Level***
Density factor	– –	++	++			– –	–	– –
Mix factor				–			–	+
Centers factor	– –	++	++	–	–	–	–	–
Streets factor				++	++			
Metro population		+		++	+			++
Average household size	+			++	++			
Percentage of working age	++				++	+		
Per capita income		++		++			–	
Adjusted R^2	0.56	0.67	0.36	0.61	0.63	0.28	0.44	0.40

Notes: + indicates a positive relationship significant at the 0.05 probability level; ++ a positive relationship significant at the 0.01 probability level; – a negative relationship significant at the 0.05 probability level; and – – a negative relationship significant at the 0.01 probability level.

Ewing and Cervero (2010) performed a meta-analysis of studies that focused on the impact of the built environment (BE) on transportation. They showed that job accessibility by auto has a relevant impact on travel behavior with an elasticity of -0.2 to VMT, similar in magnitude to the combined effect of density, diversity, and design all together. The study also identified a series of other measures demonstrating the impact of the urban form on travel behavior including the distance to downtown with an elasticity of –0.22 to VMT, and intersection/street density and distance to store have an elasticity of 0.39 and 0.25, respectively, to walking mode share. Similarly, the distance to nearest transit stop, the percentage of 4-way intersections, and the characteristics of intersections and street density had a strong impact on the use of transit. Similar to this meta-analysis, Salon et al. (2012) summarized the impact of various policies on VMT, including land use factors, pricing, public transportation, non-motorized transportation, incentives and information, and they estimated the effect on VMT with respect to policy-sensitive factors. The differences of this study with the former is that they reviewed only evidences that gave them the possibility of working with disaggregate data, employing before and after research design, using control groups, directly estimating factors that impact VMT, and properly reporting elasticities and (or) marginal effects.

Much of the research addressing this interaction has been directed toward establishing the *causality of land use on transportation*. This approach assumes a one-way relationship of causality. However, in many cases, this relationship may indeed be more complex, for instance due to the effects of travel attitudes affecting residential neighborhood decisions. Researchers began to take into account attitudes as determinants of residential location and travel behavior. For example, Handy, et al. (2005) explored the phenomenon of self-selection showing how using a simple cross-sectional analysis might lead to the conclusion that travel behavior is influenced by attitudes and not by the built environment. However, through the development of a quasi-longitudinal analysis a causal link is established between built environment and travel.

Aditjandra (2013) also explored the impact of land use on travel behavior through a study in northeast England. The study compared a statistical micro-study model based on surveys from ten neighborhoods, with a macro-study transportation demand land use model with a compaction, market-led dispersal, and planned expansion scenario. The study found that attitudes had a larger impact on travel behavior than land use.

Bhat and Guo (2007) used a joint mixed multinomial logit-ordered response model with data from the San Francisco bay area to find that built environment variables do impact residential choice and vehicle ownership and identified density as a proxy variable for BE variables. Despite the varying degree of causality land use and BE variables have on travel behavior, upon review of previous work, Handy (2005) concluded that in general highways attract growth, transit can stimulate density, and smart growth can make driving alternatives easier.

Although the implementation of many land use and transportation policies often collectively refers to policies designed for *Smart Growth, s*everal specific strategies are actually contained within this larger category, including:

- Compact development
- Transit-oriented development (TOD)
- Infill development
- Active transport

Compact development is the policy manifestation associated with a large part of the literature described above linking land use density with various benefits. The intent behind compact development is that by purposely increasing density and potentially mixing land uses, urban quality of life and the livability of urban spaces can be improved.

In a report sponsored by the California Department of Transportation (Parker et al., 2002) *transit-oriented development* is defined as:

> *"Moderate to higher-density development, located within an easy walk of a major transit stop, generally with a mix of residential, employment and shopping opportunities designed for pedestrians without excluding the auto. TOD can be new construction or redevelopment of one or more buildings whose design and orientation facilitate transit use."*

A survey of 17 Transit-Oriented developments (TODs) averaged 44% fewer vehicle trips than originally estimated using the Institute of Transportation Engineer's trip generation rates (Cervero and Arrington, 2008). Specifically in California, transit adjacent residents use transit 4-5 times more than residents living elsewhere (Lund et al., 2006). Closely associated with TOD, *infill development* can be used to revitalize a distressed urban area, whereby increasing density and often moving residents to areas with high transit accessibility.

Considerable literature exists on the benefits of *active transport*. The comprehensive review of the benefits of physical activity has been conducted by the US Department of Health and Human Services (2008); additional benefits include lowering negative externalities like pollution caused by auto traffic. Active transport trips may vary in length, but have been found to be generally less than 2/5 of a mile (Millward et al., 2013). In 2008, roughly 9% of automobile trips were a half mile or less and ¾ of auto trips are less than 10 miles (US Department of Transportation, 2008). The high proportion of short trips taken by automobiles suggests that the substitution of active transport can be very promising. However, other factors like the ability to carry heavy goods, transport other passengers and weather conditions generally limit the transferable to only roughly 10% of trips (Beckx et al., 2013).

2.2 Model Based Policy Analysis

Many improvements and modern applications in the field of travel demand modeling have been developed from the time the first methodology to determine travel patterns from land use inputs was theorized by Robert Mitchell and Chester Rapkin (1954). The landscape of travel forecasting models has changed considerably over the years, as an effect of continuous advancements in modeling methodologies and the technological innovation that has allowed for more complex modeling frameworks and faster computation of results. The scale of modern travel demand models varies considerably from local, regional and statewide levels, depending on the specific purposes of each modeling study.

The earliest form of travel demand forecasting models used a trip-based modeling approach, which was first applied in the Detroit Metropolitan Area Traffic Study, and then the Chicago Area Transportation Study (cf. Mees, 2009). The use of these models was later standardized by the Bureau of Public Roads with their inclusion into the 3C planning process (as discussed in Weiner, 1997). The primary unit of analysis of these models is "trips", which can are generally defined based on the use of one mode of transportation to travel from an origin to a destination. These models rely on finite steps to generate trips and assign them to a network. The traditional four main steps used in these models are: trip generation, trip distribution, mode choice, and route assignment. Over time, feedback loops have been incorporated into travel demand models to allow for updating inputs in previous steps.

Common characteristic to the various approaches, modeling simulations are generally performed using traffic analysis zones (TAZs) of varying sizes depending on the scale of the models (i.e. statewide model use larger zones than regional or local). Being mainly aggregate in nature, early models were designed to provide general effects of infrastructure changes. As limitations of trip-based models grew, newer tour-based models have gradually replaced their use, expliciting the concept of trip chaining – the relationship between trips taken from one origin to one or many destinations and back again (Adler and Ben-Akiva, 1979). More modern applications, following the concept of travel as a derived demand from activity participation, as theorized by Jones (1977) and others, led to the genesis of activity-based models (For a review of the deficiencies of older-generation trip-based models, i.e. credibility and limitations, and on the advantages of disaggregated models, cf. Khademi and Timmerman, 2011; Kitamura et al., 1996; Recker and Parimi, 1999; Pendaya et al., 2002; Flybjerg et al, 2002; Walmsley and Pickett, 1992; Stopher, 1993).

Despite suffering from some lingering limitations like relatively large zones for origins and destinations and other input data used in travel modeling frameworks, modern microsimulation models can base travel decision behavior at a disaggregate level for specific person types, which enables a wide range of in-depth policy analysis that were not possible before. Today, travel demand models are used to test a variety of policies at various levels of spatial aggregation using several different assumptions and land use simulations. Shiftan and Ben-Akiva (2011) point to four key policies that all activity-based models (ABM) can and should be able to analyze: "demand management, land-use policies, information communication technology, and transit improvements" (p. 520). Moreover, due to their better representation of the individual decision-making processes, activity-based models can capture wider impacts, including possible indirect and/or synergic effects of multiple policies (Shiftan and Suhrbier, 2002).

Activity-based travel modeling has been used extensively to analyze the effect of policies on transportation emissions. Two early examples of large scale applications in this field include the Landelijk Model's application to the National Environmental Plan in the Netherlands and The Norwegian Ministry of Transport's model, which both concluded that while current levels could be maintained under their model framework, only marginal reductions in fuel usage or CO_2 emissions could be obtained from private transport (Bradley and Gunn, 1993). In another study, a model developed for the Portland, OR area integrated with the Environmental Protection Agency (EPA)'s MOBILE5 model analyzed the impact of three policies: 1. increasing parking cost and tolls, 2. doubling the share of telecommuting, and 3. the transit improvements of halving bus fares and waiting times (Shiftan and Suhrbier, 2002). The study also analyzed the synergic effects on travel when combining the policies into one model scenario. The results of this analysis showed that doubling the share of telecommuting had the largest impact on tour generation, while the transit improvements yielded the highest modal shift. The combination of the policies yielded the maximum travel reduction, although it did not reach the same level from the sum of the individual effects of each policy. A similar approach was used with the Toronto activity-based travel model TASHA and vehicle emission, meteorology, and air dispersion models (Hatzopoulow and Miller, 2010). This study built the framework to output link based and zonal based emission levels, but did not analyze policy implications.

As an additional advantage from the use of these models, the disaggregate methods used in ABM enable analysis of individualized health impacts from travel. These health impacts can range from negative effects like exposure to pollutants to positive effects like increased walking or biking. One study in Belgium used the output from the microsimulation model FEATHERS to estimate elemental carbon using the emission model MIMOSA, roadway emission model IFDM, and the background dispersion model AURORA to analyze health effects (Dhondt et al, 2012). They also used the FEATHERS model to analyze health effects of road safety from crash data by mode, and health effects from active transport by converting time spent actively traveling to its metabolic equivalent. The study highlighted that the policy of increasing fuel price by 20%, due to lower car travel and increased active transport, resulted in a 2.5% decrease in deaths from EC concentration, 2.6% from active travel, and 5.02% from traffic crashes.

Numerous studies have recently looked at the disparity in transport investment benefits across populations. A study by Lemp and Kockelman (2009) investigated the spatial and demographic distribution of consumer surplus with the application of an ABM for a base scenario and three policy-related scenarios simulating respectively a freeway lane expansion, more centralized employment, and the introduction of a road pricing (toll) policy in the urban area of Austin, TX. All scenarios were compared to the base: the freeway expansion mostly benefited those closest to the expansion; the centralized employment scenario benefited those in the center city; finally, the toll introduction scenario benefited those living furthest away from the toll roads. Activity base models also allow for better identification of communities of concern based on the population that meets a given criteria versus a zonal identification procedure based on the zonal average of the metric used with TDMs (Castiglione et al, 2006). This new classification was used in an equity analysis in San Francisco to report the variation in measures of mobility and accessibility between the baseline and an alternative scenario with more transit improvements across five communities of concern: no vehicles, low income, female head of household with children, single-parent households, and by gender. The greatest differences found in mobility were that the communities of female head of households with children and single parents showed virtually no change while the average time savings across the whole county was 0.11 minutes. In terms of accessibility, very little difference was found between communities of concern and the general public in this study.

Generally, large scale multi-policy models are created for large metropolitan areas. In the Metropolitan Planning Organizations (MPOs) formed under the Federal-Aid Highway Act of 1962, regional travel modeling efforts have grown significantly within the last 20 years, due to the Clean Air Act of 1990, the Intermodal Surface Transportation Efficiency Act in 1991, and the Transportation Equity Act in 1998. During this time, the land use transportation connection has evolved as a prominent component of travel model based regional analysis. In California, all large MPOs, including the Southern California Association of Governments (SCAG) in the Los Angeles region and the Metropolitan Transportation Council (MTC) in the San Francisco Bay area (the two largest metropolitan areas in the state) use scenario testing to evaluate policies and provide sensitivity analysis on infrastructure investments. They use modeling results to discuss policy options and gain insight from the public's evaluation of different scenarios.

New endogenously derived land use transportation models as theorized by Kim (1983) explicitly derive travel demand from land use variables in dynamic modeling frameworks. Exogenous land use components in transportation models use land use forecasts to derive transportation effects. For example, a study by Rodier, Johnston, and Abraham (2002) simulated an increase in vehicle operating costs coupled with expanding light rail, transit oriented development and rail and transit improvements, using both the micro-simulation model SACMET96 and the land-use transportation model named MEPLAN. The results of the study suggest that specific land use and transit policies reduce VMT by 5-7%. When coupled with pricing, policy reductions of 9-10% were found. For an extensive review of land use forecasting models, cf. U.S. Environmental Protection Agency (2000).

Bartholomew (2007) used regional simulation methods in order to forecast the effects of various growth options for 23 different study areas, and found that the compact scenario averaged 8 percent fewer total miles driven than a business-as-usual (maximum reduction of 31.7). This reduction is primarily influenced by five major factors, known as Ds (Density, Diversity, Destination accessibility, Design, and Distance to transit). Table 2-2 reports the results from the best-fitted model developed by the author to explain VMT reduction relative to business-as-usual trends.

Table 2-2: Best-Fit Model of Percent VMT Reduction Relative to Trend (source: Bartholomew, 2005)

	Coefficient	t value	P value
Difference in density (% above trend)	-0.074	-1.48	0.15
Centralized Development	-1.50	-2.13	0.037
Mixed Land Uses	-4.64	-2.15	0.036
Population growth (% over base)	-0.068	-2.02	0.056
Coordinated Transportation	-2.12	-1.01	0.33

Many researchers have applied simulation methods to forecast the impact of various development patterns on smaller scale areas in specific project level analysis. One such study performed by Jerry Walters et al. (2000) found that infill development can decrease VMT per capita up to 35% compared to sprawl expansion. In this study they compared the impact of building a very dense, mixed used development in Atlanta, GA, versus spreading an equivalent number of residential and commercial units to 3 different suburban areas. They found that regardless of the impact of other complimentary measures and policies like pricing, compact development would lead to 7 to 10 percent decrease in total CO2 emission in 2050.

On the other end of the modeling spectrum interregional models have been increasingly used in the US, Europe, and Asia. These may range from intercity frameworks like the high speed rail model in the Tokyo-Nagoya-Osaka corridor to statewide and countrywide modeling frameworks in Europe. A survey of a number of U.S. statewide models discussed the broader concepts of capabilities of these existing tools, their major uses, objectives and level of spatial aggregation. From the survey results, most statewide modeling work is directed towards corridor planning (National Research Council, 2006); however to date, the development of detailed activity-based models that allows simulation of travel behavior at the interregional and statewide level is still rare. This is the approach that is used in this project, through the application of the CSTDM to simulate future transportation scenarios in the state of California.

3. Sustainable Community Strategies

The growing concerns about future transportation trends and their negative impacts on the environment, including greenhouse gas emission and resource depletion, have prompted legislators in the state of California to establish an innovative policy framework in this field. Assembly Bill 32 (AB32) “The California Global Warming Solution Act”, as an important milestone, required California to reduce its GHG emission to 1990 levels by 2020. This means California is required to cut about 30% GHG emission from business-as-usual trends projected for 2020. To achieve this reduction, AB32 asked California Air Resource Board (ARB) to develop a comprehensive scoping plan that provides the outline for the actions to reduce GHG emission.

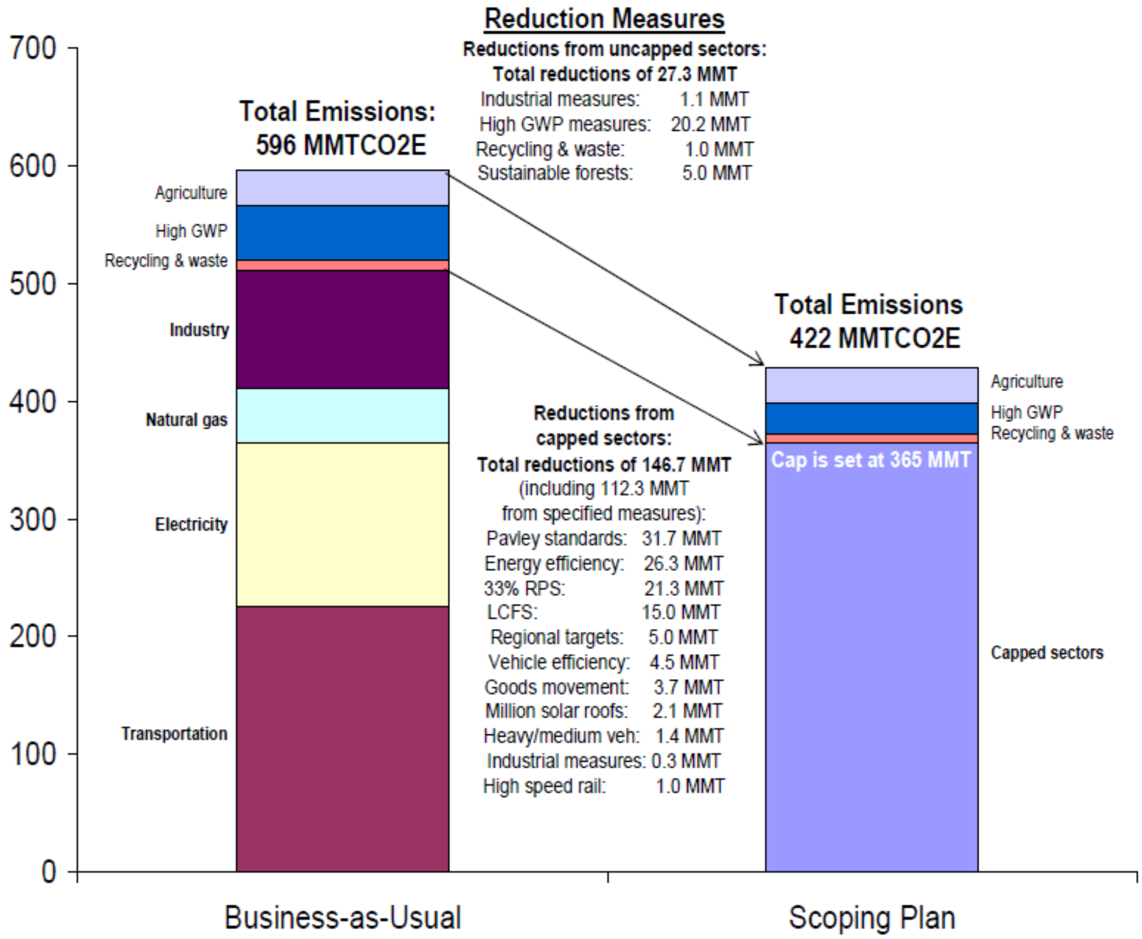

Figure 3-1: California Greenhouse Gas Emissions in 2020 and Recommended Reduction Measures (California Air Resources Board, 2008)

The key element of the Climate Change Scoping Plan can be summarized as follows (California Air Resources Board, 2008):

1- Expanding and strengthening existing energy efficiency programs as well as building and appliance standards;
2- Achieving a statewide renewable energy mix of 33 percent;

3- Developing a California cap-and-trade program that links with other Western Climate Initiative partner programs to create a regional market system;
4- Establishing targets for transportation-related greenhouse gas emissions for regions throughout California, and pursuing policies and incentives to achieve those targets;
5- Adopting and implementing measures pursuant to existing State laws and policies, including California's clean car standards, goods movement measures, and the Low Carbon Fuel Standard;
6- Creating targeted fees, including a public goods charge on water use, fees on high global warming potential gases, and a fee to fund the administrative costs of the State's long term commitment to AB 32 implementation.

Error! Reference source not found. illustrates how this scoping plan could result in GHG reduction for 2020.

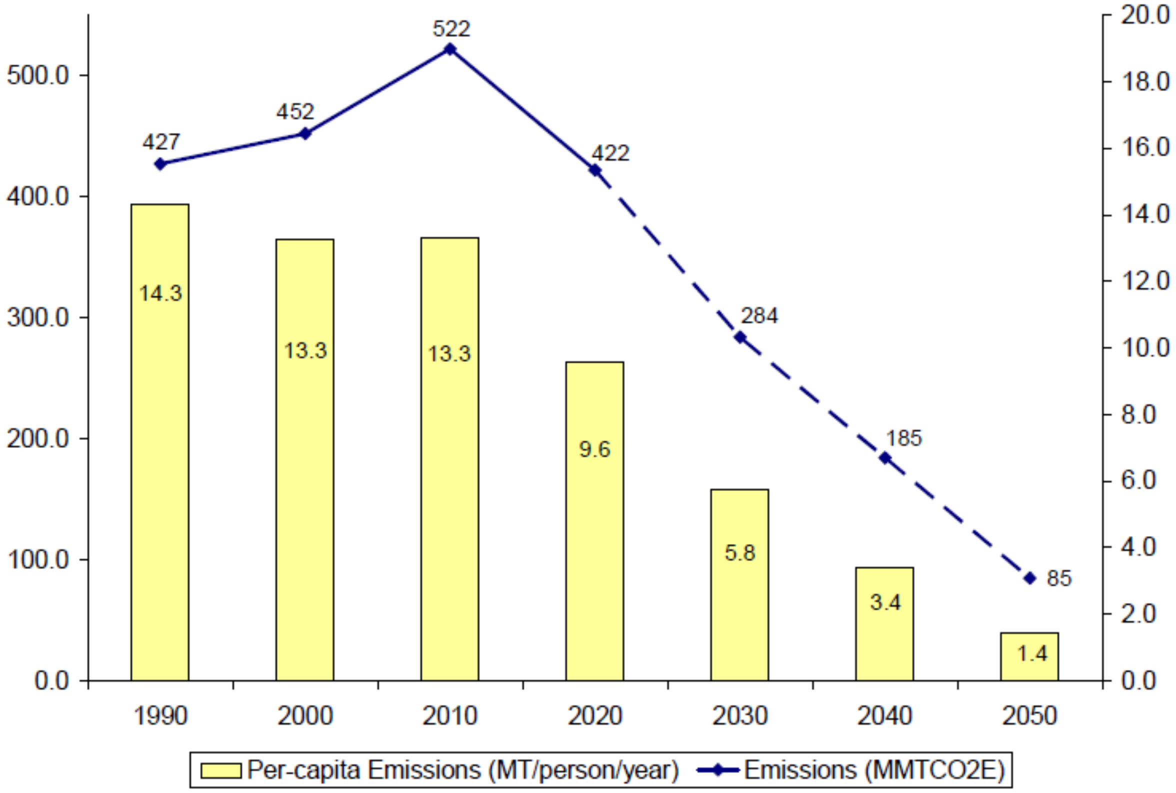

Figure 3-2: Emissions Trajectory Towards 2050 (California Air Resources Board, 2008)

In addition, the California Governor's Executive order S-3-0-5 from 2005 mandates that California reduce GHG levels by 80% from their 1990 level by 2050. Figure 3-2 shows a linear path trajectory that would be required to achieve the proposed reductions from 2020 AB32 emission targets to the 2050 goal.

To arm AB 32 with stronger tools, Senate Bill 375, the Sustainable Communities and Climate Protection Act, was approved in 2008, mandating regional agencies to integrate their development patterns and plans for transportation investments in order to obtain reductions of GHG emissions from passenger vehicles, while ensuring that the approved plans meet other planning needs and regional objectives. According to SB375, local governments and other stakeholders need to work together within a region to achieve GHG reduction goal through:

1. Integrated development patterns;
2. Improved transportation planning and other transportation policies.

As part of the development of these plans, the California Air Resources Board proposed a comprehensive three-prong strategy to reduce GHG emissions from light duty vehicles in California, which accounted for approximately 37.5% of total GHG emission in California, according to California ARB. This three-legged stool is at the genesis of the landmark legislation sparkled by AB 32. Accordingly, SB 375 Section 1 article c states:

> "*Greenhouse gas emissions from vehicles can be substantially reduced by new vehicle technology and by the increased use of low carbon fuel. However, even taking these measures into account, it will be necessary to achieve significant additional greenhouse gas reductions from changed land use patterns and improved transportation. Without significant changes in land use and transportation policy, California will not be able to achieve the goals of AB 32*."

The cited article reflects the importance of land use pattern and transportation policies in achieving AB 32 GHG emission reduction goal. Moreover, under SB375, ARB with the consultation of metropolitan organizations (MPOs) developed a set of passenger vehicle GHG emission reduction targets for 2020 and 2035.

Table 3-1: SB 375 Mandated GHG per Capita Reduction Targets

MPO Region	Targets *	
	2020	2035
SCAG	-8	-13
MTC	-7	-15
SANDAG	-7	-13
SACOG	-7	-16
8 San Joaquin Valley MPOs	-5	-10
6 Other MPOs		
Tahoe	-7	-5
Shasta	0	0
Butte	+1	+1
San Luis Obispo	-8	-8
Santa Barbara	0	0
Monterey Bay	0	-5

* Targets are expressed as percentage change in per capita greenhouse gas emissions relative to 2005

In order to reach these targets, SB 375 requires MPOs to prepare a Sustainable Community Strategy (SCS) to be included in the Regional Transportation Plan (RTP), as a package of policies designed to meet the transportation and housing needs of the regions' population while ensuring the long term environmental sustainability of California's communities. Shifts in land use patterns in accordance with these strategies are expected to emphasize compact, low-impact growth in urban areas instead of development of greenfields. As a result, communities would benefit from improved accessibility to transit, increased job-housing balancing and the preservation of open space and agricultural fields.

Rodier (2009) studied the potential impacts of land use and transit strategies on GHG emission, noting that the inclusion of other measures such as pricing policy will result in more GHG emission reduction. Several studies in the international literature were reviewed and classified by the area type, population size and transit mode share, and estimated changes in VMT and GHG that might be achieved through changes in policies related to transit, operation cost and land use across different time spans. When analyzing a single scenario, Rodier found that pricing, particularly VMT pricing, has the highest impact on reduction of VMT and its by-product. Additionally, she found that the combination of scenarios, including pricing, transit improvement and land use can reduce VMT from 3.9% to 15.8% in a 10 to 40 year time span. Evidence was also found that travel demand models may be not well suited for travel demand and policy analysis in the era of global climate change. This is principally because they can underestimate VMT reductions caused by changes in various policies due to various model restrictions.

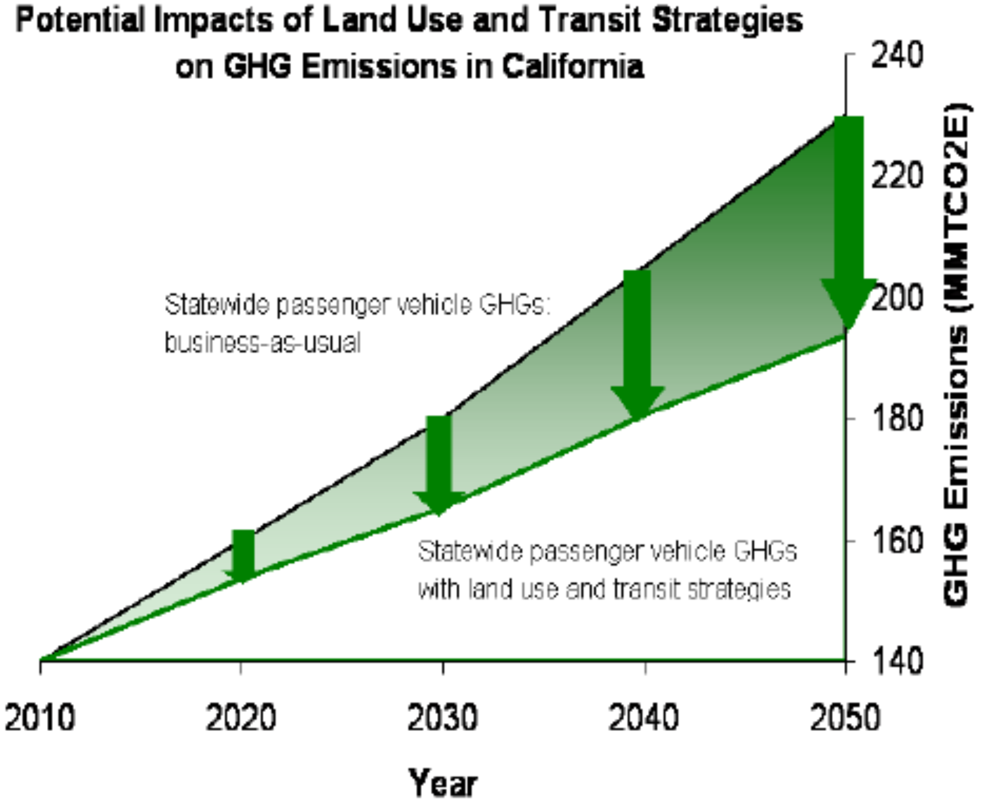

Figure 3-3: Potential impacts of land use and transit strategies on GHG emission in California (California Air Resources Board, 2008)

Besides GHG reduction, the SCSs will improve quality of life through increased accessibility to various mobility options and through the diversification of housing types near jobs, recreation, and public services. Other goals that can be achieved through the implementation of SCS are:

1. Preservation of agricultural land, open space and habitat
2. Improved water quality
3. Positive health effect
4. Reduction of smog forming pollutant

Section 4 article b 1 of the bill outlines the required policy elements for agencies with populations exceeding 200,000 including:

- Measures of mobility and traffic congestion
- Measures of road and bridge maintenance and rehabilitation needs
- Measures of means of travel
- Measures of safety and security
- Measures of equity and accessibility

The same section specifically outlines the tasks of the SCS to identify:

- The general location of land uses, densities, and intensities
- Areas within the region to house the current and future populations of the region
- Areas to house an eight year population projection
- A transportation network to serve the needs of the area
- The best practically available scientific information for resource area and farmlands
- A forecasted development pattern with integrated transportation policies to achieve the GHG reduction target.

Each MPO's strategy needs to include an action plan that describes the specific programs and actions needed to achieve the policy goals. One of the key benefits of SB 375 is the streamlined environmental review under the California Environmental Quality Act (CEQA) for transit priority projects. These projects are defined as those designed for relatively dense areas (20 dwelling units per acre) within a half mile of a transit stop or corridor with headways of 15 minutes or less. Each published SCS needs to specifically outline these areas.

Table 3-2: Timeline and Approval of Sustainable Community Strategies in California

Metropolitan Planning Organization	Tier	Adopted	Date of Adoption	GHG/Capita 2035 % Reduction Target	Notes
SACOG - Sacramento	1	Yes	April 19, 2012	-16	
SANDAG – San Diego	1	Yes	October 28, 2011	-13	
SCAG – Southern California (Los Angeles)	1	Yes	April 4, 2012	-13	
MTC – San Francisco Bay Area	1	Yes	July 18, 2013	-15	
SBCAG – Santa Barbara	1	Yes	August 15, 2013	0	
BCAG – Butte	1	Yes	December 13, 2012	+1[1]	
TMPO – Tahoe	1	Yes	December 12, 2012	-5	
SRTA – Shasta	2	No	-	0	
SLOCOG – San Luis Obispo	2	No	-	-8	Preliminary SCS (2010)
AMBAG – Monterey Bay	2	No	2014	-5	
KCAG – Kings	2	No	2014	-10	Valley Visions SCS
MCAG – Merced	2	No	2014		
MCTC – Madera	2	No	2014		
KCOG – Kern	2	No	2014		
StanCOG – Stanislaus	2	No	2014		
TCAG – Tulare	2	No	2014		
COFCG – Fresno	2	No	2014		
SJCOG – San Joaquin	2	No	2014		

Note: [1]This MPO was allowed to have a limited increase in the amount of GHG/capita in the environmental targets.

Table 1 reports the progress that each MPO in California has made in creating its SCS, to date. In the table, we group MPOs into two clusters that classify the stage of development of the SCS plans and consequently the type of information that could be accessed for each specific MPO for this research. Tier 1 defines MPOs with adopted SCS documents whose data could be fully used in the study. Tier 2 includes the rest of the state, i.e. the other MPOs without a published SCS.

Contained in each MPOs' RTP, several investment strategies are described under various groups of possible objectives to be implemented, as for instance *Making Better Use of What We Have* (cf. SANDAG RTP Ch. 7), *Offering More Travel Choices* (cf. SANDAG RTP Ch. 6), *Where We Live, Where We Work* (cf. MTC RTP Ch. 3), *Policies and Supportive Strategies* (cf. SACOG RTP Ch.6), *Transportation Investments* (cf. SCAG RTP Ch. 2), *Policy Element* (cf. SBCAG RTP Ch. 4) and *Funding and Implementation Strategy* (cf. TMPO RTP Ch. 6). A number of California's MPOs have included chapters in their RTP specifically devoted to the development of their SCS. These include:

- *Forging a Path Toward More Sustainable Living: Sustainable Communities Strategy* (cf. SANDAG RTP Ch. 3)
- *Sustainable Communities Strategy* (cf. SCAG RTP Ch. 4)
- *Sustainable Communities Strategy & Performance Element* (cf. SBCAG RTP Ch. 6)
- *Sustainable Communities Strategy* (cf. TMPO RTP Ch. 3)

These policy documents, together with additional estimates distributed by the California ARB (2013a, 2013b, 2013c) summarize the strategies developed by each MPO, together with the actual greenhouse gas (GHG) reduction estimates.

For the region of Sacramento, the State Capital, the Sacramento Area Council of Governments (SACOG) estimates that their region will achieve GHG reductions of 9% by 2020 and 16% by 2035. To achieve these reductions, the following general strategies are outlined in their (cf. SACOG 2012 RTP Ch. 6; California Air Resources Board, 2013a):

- An emphasis on small-lot and attached housing;
- Locate the majority of new housing and jobs within the region's existing urbanized areas using regional infill and re-use strategies;
- Emphasize operational improvements over new roadway capacity projects;
- Transfer more than $2 billion dollars from roadway to transit projects that are focused in compact, mixed-use areas of the region;
- Invest in high frequency (15 minute or better) bus transit service;
- Increase investment in biking and walking along existing urban corridors.

Figure 3-4 shows an estimate of VMT per capita reductions in the SACOG region provided by the California Air Resources Board (2013a).

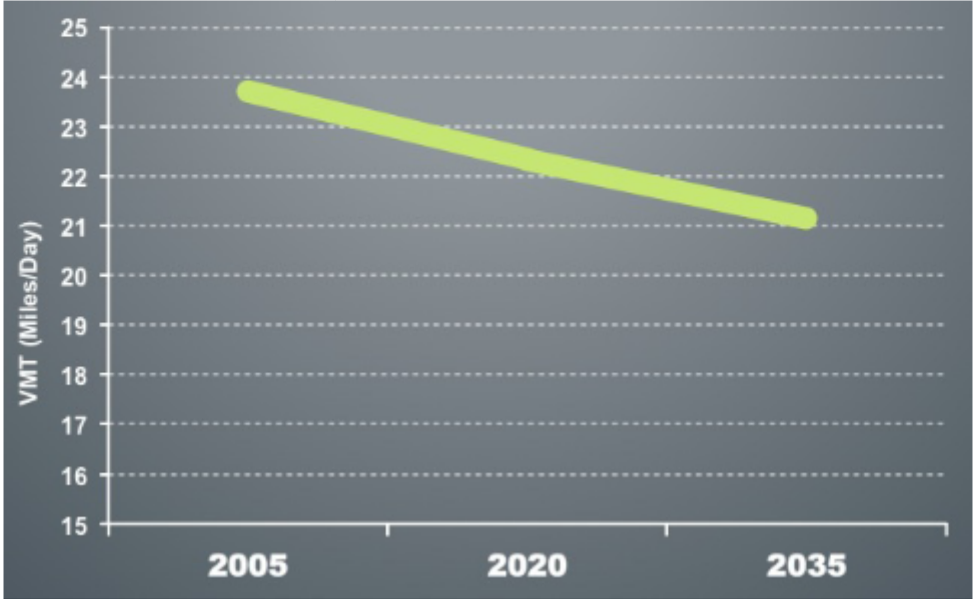

Figure 3-4: Daily VMT per Capita Change from 2005 to 2035 in SACOG region (California Air Resources Board, 2013a)

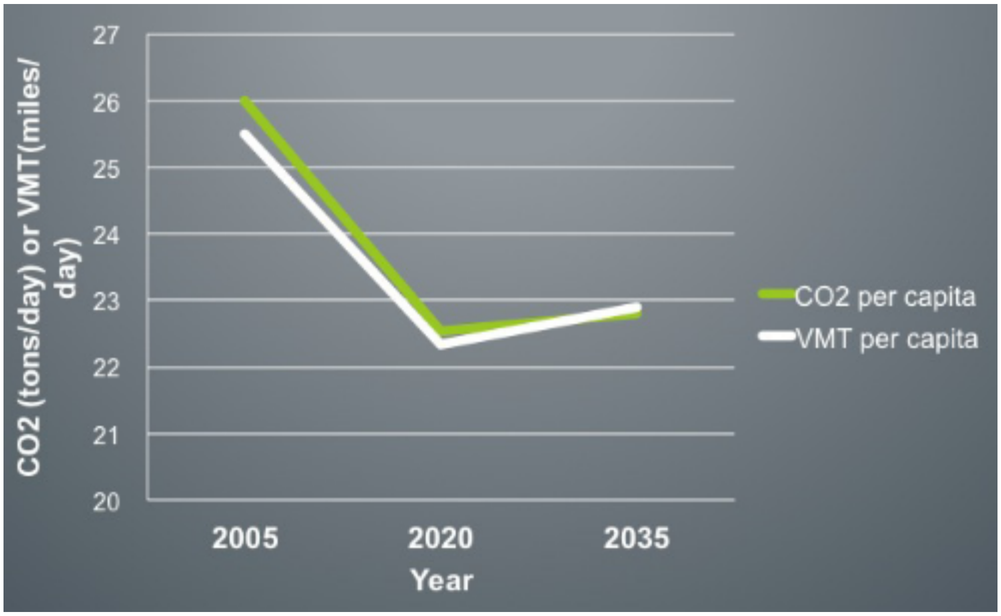

Figure 3-5: Daily VMT and CO_2 per Capita Change from 2005 to 2035 in the SANDAG region (California Air Resources Board, 2013b)

SANDAG estimates GHG reductions of 14% by 2020 and 13% by 2035. They plan to achieve these reductions by implementing the following changes (California Air Resources Board, 2013b):

- Local land use plans and the region's Smart Growth Concept Map show the region's plans for compact and transit-oriented development with support from transportation investments;
- Significant improvements to the region's transit network with new investments in light rail and bus rapid transit services;
- Transportation system management, demand management, and pricing policies;
- Large investment in biking and walking.

Error! Reference source not found. shows the estimate of VMT per capita and CO_2 per capita reductions in SANDAG according to the California Air Resources Board (2013b).

SCAG estimates that their region will achieve GHG reductions of 9% by 2020 and 16% by 2035. This latter estimate includes a 2% reduction due to policies not simulated in their regional travel model as presented in SCAG's 2012 RTP (p.13) of the performance measures chapter. To achieve these reductions, the following general strategies are proposed (California Air Resources Board, 2013c):

- Compact growth in areas accessible to transit with increased multi-family housing;
- New housing and job growth focused in High Quality Transit Areas (HQTA) with half of all new development focused on 3% of the region's land area;
- Better access to transit caused by expanded transit investment representing 20% of total budget;
- Reduced vehicle miles traveled through innovative finance mechanisms;
- Investments in biking and walking infrastructure.

Figure 3-6 shows the estimate of VMT per capita reduction in the SCAG region resulting from these policies (California Air Resources Board, 2013b).

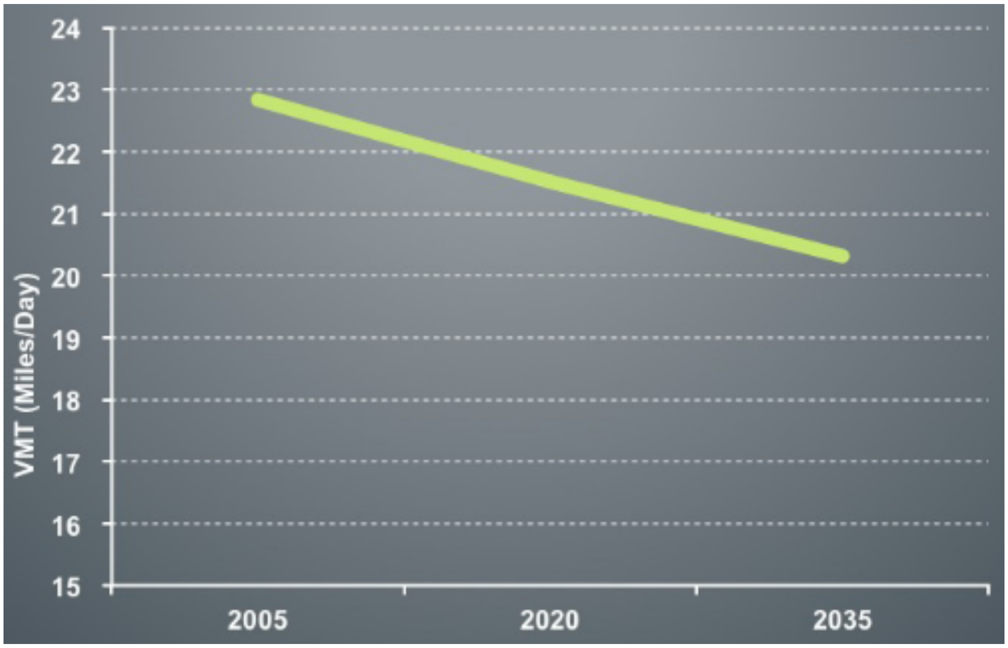

Figure 3-6: Daily VMT per Capita Change from 2005 to 2035 in the SCAG region (California Air Resources Board, 2013c)

MTC estimates that their region will achieve GHG reductions of 10% by 2020 and 16% by 2035 (Metropolitan Transportation Commission, 2013a, Ch. 5, p. 99). To achieve these reductions, the following general strategies are outlined in the investment chapter of their newest RTP:

- Focus future growth into transit oriented infill priority development areas;
- Improve existing transit services while expanding the system by extending existing lines and adding new ones;
- Innovative pricing policies including cordon pricing and incentives for fuel efficient vehicles and vanpools.

Figure 3-7 shows the estimate of CO_2 per capita in the MTC region, according to their predicted traveler responses supplementary report (Metropolitan Transportation Commission, 2013b, Table 12 p. 63).

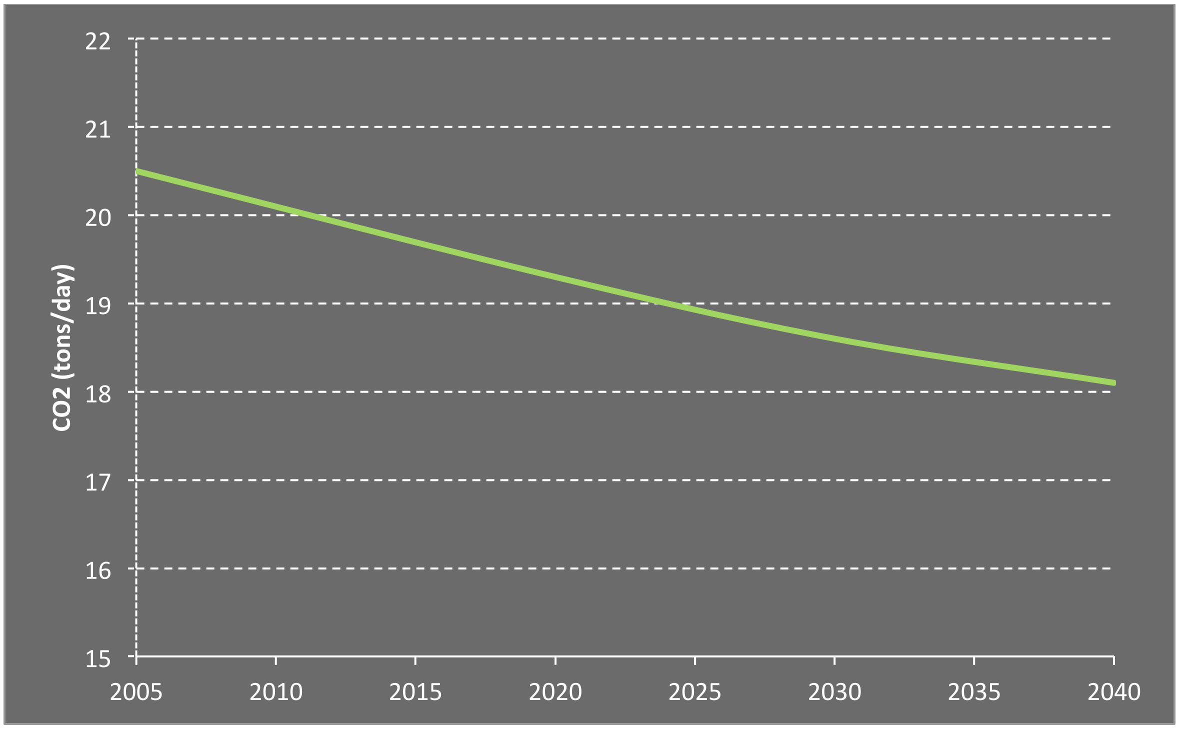

Figure 3-7: MTC's Daily CO_2 per Capita Change from 2005 to 2040 (Metropolitan Transportation Commission, 2013b, Table 12 p. 63)

Information gleaned from these documents is useful to inform about the ways MPOs plan to reduce GHG and satisfy the requirements of SB 375. Given the standard set of regulations for each MPO (aside from the divergent GHG reduction targets), the policies produced remained generally consistent across MPOs, even if the methods of development differed. Across MPOs, multiple future scenarios were envisions, tested, and presented to the public for comment.

For example, Chapter 3 of the MTC's RTP documentation outlines a detailed methodology that uses growth factors for allocating future households to 3 area types:

- Job-Rich cities with priority development areas (PDAs);
- Existing transit-connected areas;
- Those lacking sufficient affordable housing.

PDAs are nominated and defined as a place type (regional center, transit neighborhood, mixed-use neighborhood, etc.) by local jurisdictions. These are areas where future growth will be directed, as MTC seeks to facilitate a more comprehensive planning strategy. In allocating future households, MTC used outcomes from their travel demand model to redefine land use inputs. They placed areas into transit tiers based on their transit access, and households into VMT per household tiers based on their car usage. They then used these tiers to adjust the growth rate in population towards transit focused areas. Figure 3-8 outlines MTC process to forecast employment and housing using SB 375 and the MPO's long-term growth forecasts as inputs. MTC discussed scenarios created from this initial processing in public forums.

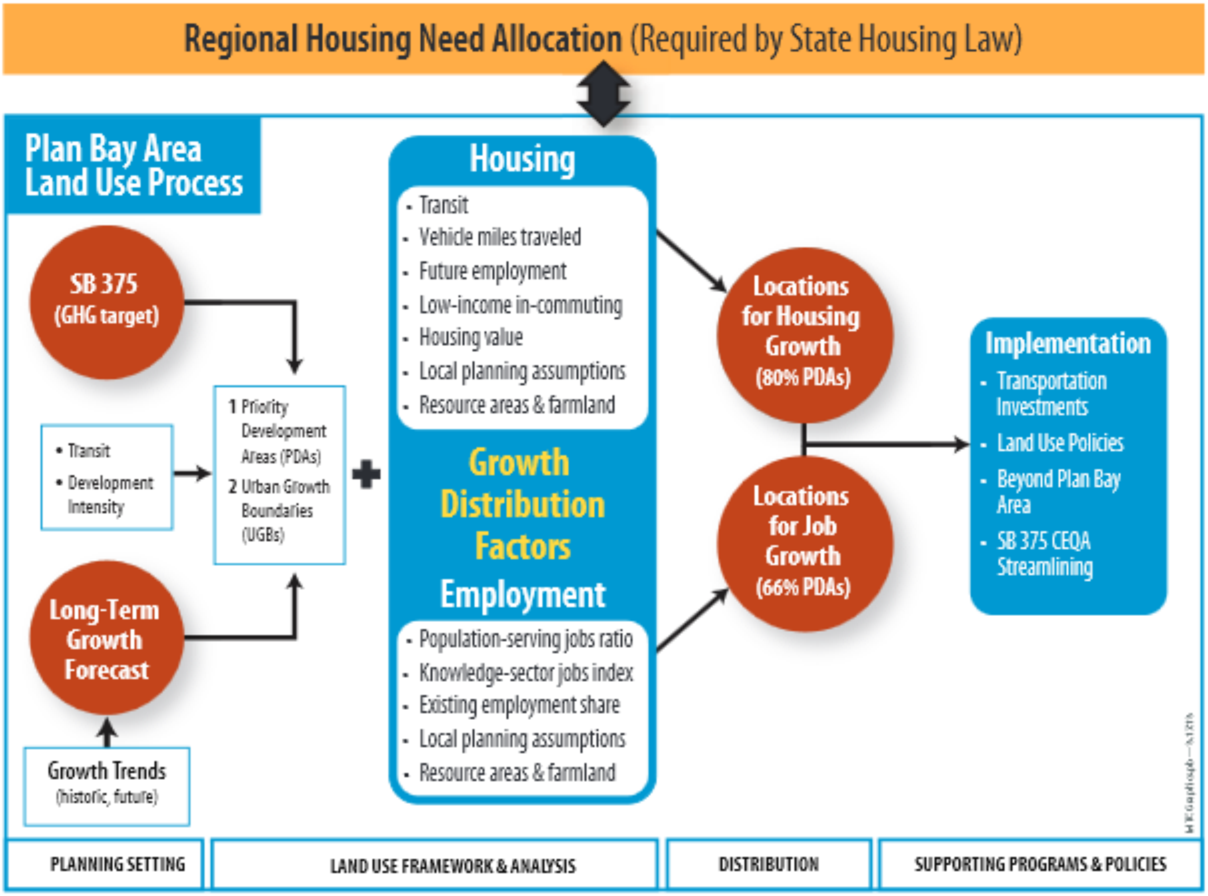

Figure 3-8: The Metropolitan Transportation Commission's (MTC) housing and employment allocation methodology (MTC RTP Ch. 3, p. 43)

SCAG defined scenarios based on the Rapid Fire model created by Calthorpe Associates (SCAG RTP/SCS Appendix, Section C). Figure 3-9 outlines the scenarios presented to the public for comments.

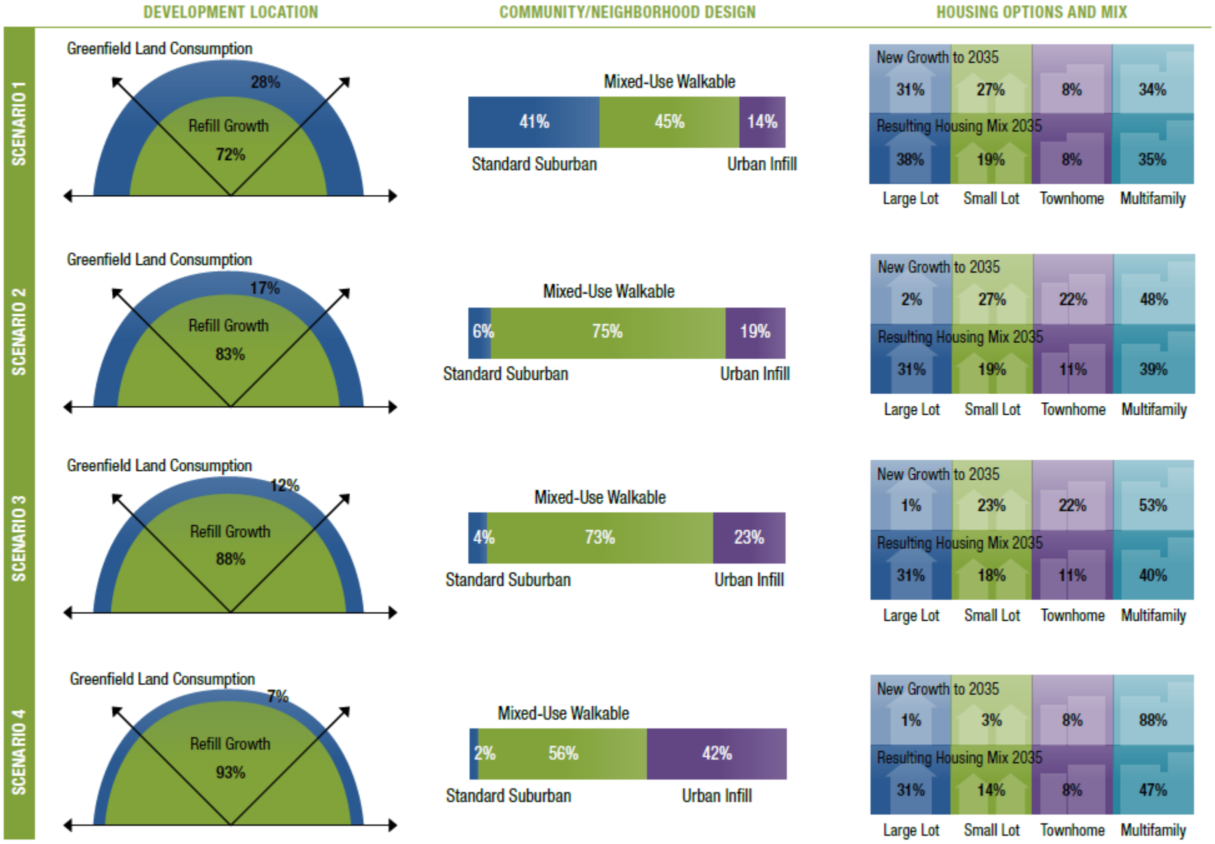

Figure 3-9: Southern California (SCAG) land use scenarios (SCAG RTP Ch. 4, p. 117)

Smaller MPOs used an approach similar to larger MPOs, but with a more detailed analysis for small scale areas. For example, the performance section of the SCS chapter of the Santa Barbara County Association of Governments (SBCAG) discusses how local growth in the South Coast will can be accommodated while targeting an overall regional decrease in congested VMT:

> *"The only viable approach to accommodating growth and simultaneously meeting SB 375 emission targets is an approach that relies on a land use solution that addresses jobs/housing balance using an infill approach within existing urban areas."* (SBCAG RTP, 6-44)

SBCAG defined eight scenarios using the same regional population and employment forecasts, four of which met the requirements of SB 375. The final SCS Scenario combined a TOD/infill scenario with an enhanced transit scenario.

4. Modeling Framework

The California Statewide Travel Demand Model (CSTDM) is a large-scale modeling framework designed to forecast travel demand, support transportation planning and the evaluation of policies in the State of California. This modeling framework addresses all major components of long and short distance travel demand using an activity-based micro-simulation approach during four time periods in an average weekday. It integrates five main travel demand sub-models:

6. Short Distance Personal Travel Model (SDPTM)
7. Short Distance Commercial Vehicle Model (SDCVM)
8. Long Distance Personal Travel Model (LDPTM)
9. Long Distance Commercial Vehicle Model (LDCVM)
10. External Trip Model (ETM).

These five sub-models are combined into a unified modeling framework that runs in the Citilabs CUBE platform. Travel demand flows from the five models are assigned to the respective road and public transportation networks in the transportation assignment step of the modeling framework. The main model architecture and assignment process uses several components from the Citilabs CUBE platform, and specific sub-models and additional script components activated by the model run in Python and Java. The modeling system runs iteratively until the convergence criteria are fulfilled. Figure 4-1 shows the inputs, model components, and outputs produced by the CSTDM. A full model overview as well as detailed descriptions of each component specified in this section can be found on the UC Davis Urban Land Use and Transportation Center (ULTRANS) website: http://ultrans.its.ucdavis.edu/doc/cstdm-documentation.

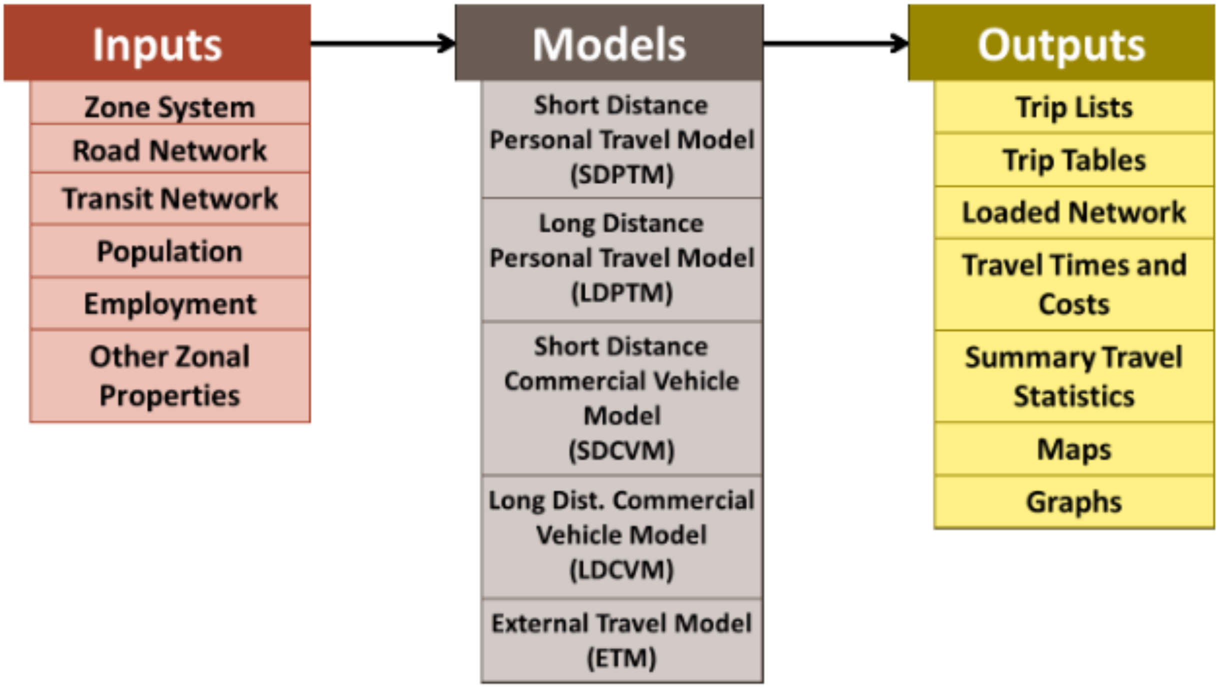

Figure 4-1: CSTDM Model Overview

The CSTDM explicitly models all relevant transportation modes for both short and long distance travel, i.e. single occupancy vehicle (SOV), high occupancy vehicle with two (HOV2) or three or more passengers (HOV3), light truck, medium truck, heavy truck, local public transit (bus and rail), long distance rail, airlines, school bus, bike, and pedestrian. The CSTDM simulates travel demand for all trip purposes in the average weekday during the regular work and school seasons for four time-periods: AM Peak (from 6:00AM to 10:00AM), Midday (10:00AM to 3:00PM), PM Peak (from 3:00PM to 7:00PM) and Off-Peak (rest of the day).

The personal travel sub-models simulate personal travel for a variety of purposes using auto SOV and HOV modes. In addition, the model simulates the use of transit, bicycle and walk for short distance trips, and of air and rail travel for long distance trips. The distinction between short and long distance is defined as 100 miles. This cut-off distance was determined as an appropriate threshold separating most regular short distance trips (for work, study or other purposes) from lower frequency long distance trips (generally made for business or vacation purposes) through the analysis of travel patterns from travel survey data in California.

The SDPTM uses information generated by a synthetic population module and discrete choice models to simulate the personal travel behavior of each household member in California. The model first establishes long-term decisions (i.e. driver's license, and household auto ownership), and then generates day patterns of activity participation for each individual in the household, which are then used to generate tour and trip decisions, including purpose of the trip, final destination and mode choice. Figure 4-2 shows a graphical representation of a *day pattern*, with the inclusion of several tours and subtours, and the identification of tour and trip purposes and the various legs of the tours.

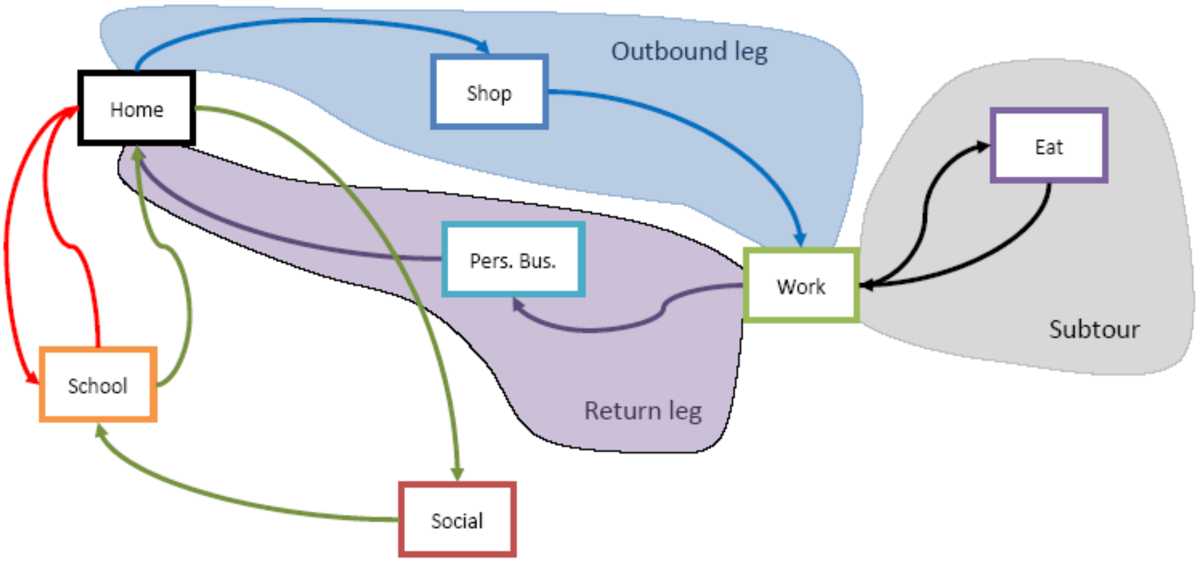

Figure 4-2: A Typical Day Pattern (with Tours and Subtours) in the CSTDM Short Distance Personal Travel Model

The Long Distance Personal Travel Model (LDPTM) simulates passenger trips for distances longer than 100 miles, and forecasts trip frequency, party size, destination, main mode, access and egress mode, and time of the day of each trip. The Short Distance Commercial Vehicle Model (SDCVM) uses a micro-simulation tour-based modeling approach to forecast both goods and service vehicle movements within a range of 50 miles, including light, medium, and heavy duty trucks. The distance of 50 miles was determined as an appropriate threshold to distinguish between short distance and long distance commercial vehicle trips through the analysis of truck movements in the State. This is in particular useful to properly model the different characteristics of short distance trips from long distance commercial movements (which are predominantly based on a hub-and-spoke system, and make a very different use of the available fleet to consolidate shipments through the use of larger vehicles over long distances). The Long Distance Commercial Vehicle Model (LDCVM) simulates long distance commercial vehicle trips using data on commodity flows throughout the state obtained from the Production, Exchange and Consumption Allocation System (PECAS) modeling framework. These numbers were then scaled according to a forecasted growth factor for future model scenarios. The External Travel Model (ETM) predicts the number of trips, the modes used, the origin, destination and time for all trips that either begin and/or end outside California crossing one of the 49 external gateways to California for both passenger and freight transportation, and the three major ports of Los Angeles, Long Beach and Oakland for freight movements. Additional details on the development of the CSTDM modeling framework and on each modeling component are provided by ULTRANS and HBA Specto (2011).

Each sub model was calibrated using data from the California statewide household travel survey, complemented by MPO travel survey data available for SANDAG, SCAG and MTC. The 2008 base model was validated using observed highway and transit volumes of a weekday in fall 2008. One major assumption inherent in this and many other travel models is that the relationships between input data and travel behavior remain consistent over time. Specifically that the sub models calibrated and validated using 2008 data will accurately predict future travel in 2035 assuming the forecasted input data is correct. This latter assumption is also a potential source of error due to the large uncertainties associated with the prediction of future geographical and demographical population.

4.1 Road and Public Transportation Networks

The road network in the CSTDM Framework is coded in the Citilabs CUBE software package. In the original CSTDM model development project, the road network was developed for the years 2000 (calibration scenario) and 2008 (validation scenario), and it includes all road links that are relevant for a statewide travel demand model. Additional information is included regarding the location of HOV lanes and dedicated ramps, bridges and tolls, and the access to all major transit and airport terminals. The update of the road network for future years was developed using information provided by the metropolitan planning organizations in the State.

Public transportation is represented by the local transit (rail and bus) services, the long-distance intercity railways and the air network. Different approaches are used for the representation of the public transportation networks, depending on the different needs and the level of relevance of public transportation services for either one or more of the five component models. The air network, which is used in the long distance personal travel model, is coded explicitly through the definition of the airports that provide intra-state commercial air services, and the characteristics of the services offered on each route (travel time, headways, average fares, and reliability). All railway services are also explicitly coded in the public transportation network. The rail network is used in both the short distance and the long distance personal travel models. It accounts for the majority of intercity, commuter railways, subway, and light rail which provide scheduled passenger services on fixed routes throughout the state.

Local transit services are modeled using a synthetic approach, based on the estimation of econometric models that represent the local transit attributes (in-vehicle travel time and out-of-vehicle waiting and transfer time) as functions of other variables used in the modeling framework, including HOV travel time, population and employment density, and the bus operator's level of service (LOS). This simplified representation of local transit services provides an efficient representation of local bus services in a statewide model reducing the amount of resources required for the initial coding and subsequent update of local transit routes and services, which would be beyond the scope of a large-scale model. In fact, bus services are provided through more than 50 local transit operators in California, with over 1500 local bus routes. The location of the specific bus routes and stops and characteristics of the service provided (headways and travel time) are also often subject to frequent modifications, and many local bus routes operate on local roads that are not included in the road network used for a statewide travel demand model, and therefore they could be difficultly modeled with an explicit coding approach in such a model.

The synthetic local public transportation functions use four main inputs:

- the *transfer areas* (broader catchment area within which a person can travel also through transfers among different operators in a region);
- the smaller *service areas* (the areas within which public transportation is generally provided by a single operator;
- the local operator's *level of service* (a single number representing the quantity of local bus service provided by each operator in a service area) and
- the *fare* (composite value, expressed in US dollars, indicating the typical fare paid by a customer for a single trip by bus).

The LOS metric measures the availability, and quantity, of transportation provided by a local operator compared to the population that is included in its areas of service, and it is numerically calculated by dividing the population served by the annual revenue miles of local bus services within a specific area.

The development of the model is based on the adoption of specific assumptions on the relationships among public transportation travel times and other relevant transportation and land use variables. The synthetic methodology is used to compute travel times by local transit for each pair of origins and destinations in the CSTDM (where local transit services are provided), and accessibility measures for railway facilities with connecting bus services, thus providing a realistic representation of the multimodal trips involving the use of both rail and bus services. Additional information on the assumptions used for the development of the synthetic methodology for the representation of local transit services in the CSTDM modeling framework, the data used for the estimation of the simplified econometric models for in-vehicle time and out-of-vehicle time and the integration of the local transit model in the CSTDM modeling framework are provided by Circella et al. (2011; *forthcoming*).

4.2 Land use and Sociodemographics

Land use inputs are incorporated in the CSTDM in the *zonal properties* model component, which characterizes the population, employment, and school enrollment for each of the 5421 traffic analysis zones (TAZs) used in the modeling framework. The zonal properties influence the travel behavior of the synthetic population modeled in the CSTDM and are used as inputs into the discrete choice sub-models. The synthetic population is created by using simulated annealing to match census targets by duplicating households from the 5% PUMS Census long form sample. Employment data for each zone is comprised of industry and occupational categories obtained from numerous sources such as the Census Transportation Planning Package, the California Employment Development Department, and OnTheMap data. To develop daily schedule as part of the short distance personal travel model, school enrolment was tabulated for elementary school (K-8), high school (9-12), and post-secondary school. The relative data were obtained from the California Basic Educational Data System, DataQuest, California Department of Education, California Post-secondary Education Commission, and the National Center for Education Statistics.

5. Creation of Policy Scenarios

This study simulates the impact on travel behavior of some transportation and land use policies that have been introduced as part of the recent metropolitan planning organizations' RTP/SCS plans through the simulation of future policy scenarios in the CSTDM modeling framework. All scenarios are run for year 2035, a particularly important year for policy purposes, as it corresponds to the year in which the second GHG reduction targets mandated by SB 375 are due.

In this study, we model future travel demand in two main scenarios. A *control* scenario was created using information on sociodemographics, future transportation and land use policies contained in the last generation of Regional Transportation Plans (i.e. previous to the adoption of the Sustainable Community Strategies, as required by SB 375). This scenario depicts a "business as usual" 2035 CSTDM scenario, created before the SCSs were published. The scenario was developed using a previously developed 2035 CSTDM scenario as the basis to generate the data input for this future scenario.

The *SCS* scenario was created using the updated data on future transit infrastructure and services and land use changes forecasted by local MPOs according to the most recent RTP/SCS documents. Therefore, the SCS scenario represents the "marginal changes" introduced with the latest generation of planning tools, compared to the previous round of RTP plans, as an effect of the approval of the recent environmental legislation.

5.1 Control Scenario

The control scenario mimics the *business as usual* transportation investments and land use strategies that were developed before the adoption of the SCSs. This scenario differs from a previous 2035 scenario that was created for the CSTDM model (as described in the documentation available at http://ultrans.its.ucdavis.edu/doc/cstdm-future-scenarios-and-model-applications) as sociodemographic values were scaled in order to match the updated forecasts on population and employment totals for 2035.[1] Table 5-1 shows summary figures for the roadway, railway, and land use inputs for the 2008 base CSTDM scenario and the Control scenario for 2035.

Table 5-1: Comparison of 2008 (Base) and 2035 (Control) Scenarios

	2008	*2035 Control*	*Difference*	*Percent Increase*
Roadway Links	237,866	246,046	8,180	3.4%
Roadway Miles	172,491	182,476	9,985	5.8%
Railway Links	868	1,196	328	37.8%
Railway Miles	3,030	5,148	2,118	69.9%
Population	38,432,601	47,627,671	9,195,070	23.9%
Employment	14,947,500	19,795,587	4,848,087	32.4%

---

[1] The Department of Finance has reduced the population forecasts in California by 5.3% from the previous forecasts from 2010 that were used to create the previous 2035 scenario.

This scenario was created to allow for a proper comparison of travel demand under the SCS scenario with pre-SCS planning conditions. This creates an experiment to study some of the changes in transportation planning in California and their potential effects on travel patterns.

For all those cases in which it was not possible to obtain full information for the creation of the 2035 control scenario from the latest RTP before the adoption of the recent RTP/SCS, data inputs were built using extension from current trends from the base 2008 scenario. An example is the bus LOS (computed as the ratio of population served/ bus revenue miles) for the 2035 control scenario. These figures were obtained from estimates made in 2008 and extended to future year's scenarios under the assumption that revenue miles would grow proportionally with population in all areas where no other sources of detailed information were directly available from previous RTPs.

5.2 SCS Scenario

The SCS scenario was created with the intent to mimic wherever possible the strategies proposed in the SCS documents that differed from previous RTPs. In particular the land use variables of TAZ population and employment were changed and distribution of land uses modified, as well as increased transit investments were added to the travel network. The population and employment totals in the 2035 SCS scenario match those of the control scenario at either the MPO level in tier 1 regions or at the county level in tier 2 regions.

As much of the highway improvements contained in the newest RTPs were also included in previous RTPs, no significant additional changes were needed to update the road networks in the modeling framework during the creation of the updated 2035 SCS scenario. Additionally, because transit and land use integration investments were the main focus of the SCSs, leaving out new highway improvements allowed this analysis to isolate the impacts attributable to the SCSs, compared to the previously adopted policies that were developed before the more stringent environmental requirements were adopted in the State of California.

Table 5-2: Comparison of Scenario Attributes

	Control	SCS	Difference	% Difference
High Speed Rail	904	904	0	0%
Intercity, Commuter, and Light Rail*	4,248	4,429	181	+4.3%
Bus Rapid Transit	0	900	900	N/A
Total Transit Miles	5,148	6,233	1081	+21.0%
Population	47,627,671	47,625,291	-2,380	-0.005%
Employment	19,795,587	19,796,536	949	+0.005%

*These transit services were combined because they use the same infrastructure. As multiple transit lines can use the same track, infrastructure additions measure the extension of accessibility and not necessarily improved operation.

The 2035 SCS scenario necessarily omits some of proposed policies contained in the RTPs/SCSs. This is especially true in the case of subregional strategies and local policies, and of the changes introduced at a local scale that cannot be represented in a statewide model. The results of this scenario show the potential impact of these combined policies if they will be implemented as currently planned.

Several combinations of policies were tested in the creation of the modeling scenarios. The final SCS scenario presented in this report is the last version of a series of SCS scenarios that tested various degrees of policy changes being introduced. The data used in these scenarios referred mostly to new policies from MPOs as the RTP/SCSs became available. Results from other partial scenarios that were created during the development of the project were also preserved in order to compare modeling outcomes and study in isolation the effects of certain policy additions.

5.2.1 Land use data

As part of each SCS, new regional housing forecasts were developed at either a parcel level (for SACOG) or a TAZ level (for the other MPOs included in this study). The primary difficulty encountered with land use data at the TAZ level of aggregation is that in most cases the TAZ system from local MPOs did not match the TAZ system in the CSTDM. Figure 5-1 shows an example of the overlap of these TAZ systems in the SCAG region.

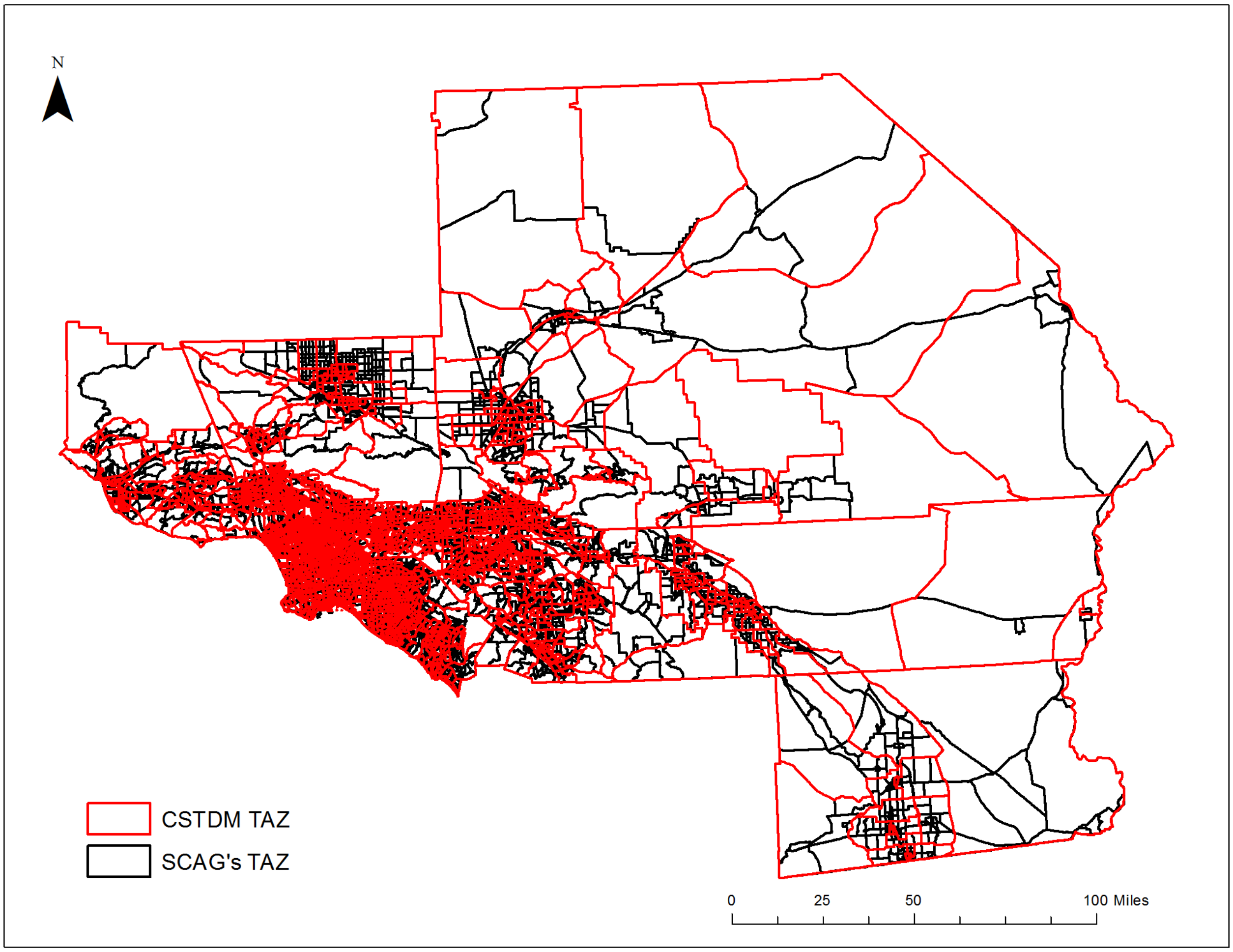

Figure 5-1: Overlap of MPO TAZ System with CSTDM TAZ System in the SCAG Region

This problem was dealt with in the initial data formulation of the CSTDM by using split ratios to convert MPO TAZ population and employment totals to the CSTDM TAZ system. This initial data process was developed for the CSTDM model to account for the non-uniform distribution of jobs and population throughout a zone. It was initiated by differentiating the MPO TAZs into two classes: nesting in CSTDM TAZs, and non-nesting. Nesting TAZs fell completely within a CSTDM TAZ, while non-nesting TAZs straddled a CSTDM TAZ boundary. The latter type necessitated allocating jobs and people to multiple CSTDM TAZs. Three methods were defined to allocate or split jobs and population from non-nesting MPO TAZs: all-or-nothing, proportional, and manual. The all-or-nothing approach assigns all TAZs variable scores to one CSTDM TAZ. The proportional approach would split the TAZ variables into CSTDM TAZs based upon the proportion of land area. The manual approach would determine the variable splits based upon the known spatial distribution of land development in an area. For example, if much of a CSTDM zone is protected forest, very little jobs or population will be allocated there.

To maintain consistency and replicability of the used approaches, the same split ratios that had been previously used were also used to convert the newly obtained MPO TAZ data to CSTDM TAZ modeling inputs. Table 5-3 summarizes the data availability and level of spatial aggregation for the land use data received from each MPO.

Table 5-3: Comparison of MPO Land Use Data

	SACOG	SCAG	MTC	SANDAG	BCAG	SBCAG	TMPO
2008 Data	✓	✓					
2010 Data			✓				✓
2020 Data	✓	✓		✓			✓
2035 Data	✓	✓		✓	✓	✓	✓
2040 Data			✓				
2050 Data				✓			
Matched Old MPO System	N/A	✓	✓	N/A	N/A	N/A	N/A
Parcel Level	✓						
Course TAZ Level		✓	✓				
Fine TAZ Level				✓	✓	✓	✓

Santa Barbara County, San Diego County, Butte County, and the Tahoe region all had TAZ systems at a much higher resolution than the CSTDM TAZ system. Therefore, a simpler spatial aggregation process was performed to import these data into the CSTDM modeling framework. The disaggregate parcel level data from SACOG was converted to the CSTDM modeling framework using an analogous process.

Several methods were envisioned to modify the synthetic population to mimic the land use policies from the recent SCSs. The figure below outlines these methods. In general, population forecasts can be defined at a variety of levels: aggregate forecasts predict the total number of residents or households for a given area (e.g. TAZ), while subpopulation forecasts predict the number of residents or households in different subgroups (e.g. low income households) for a given area.

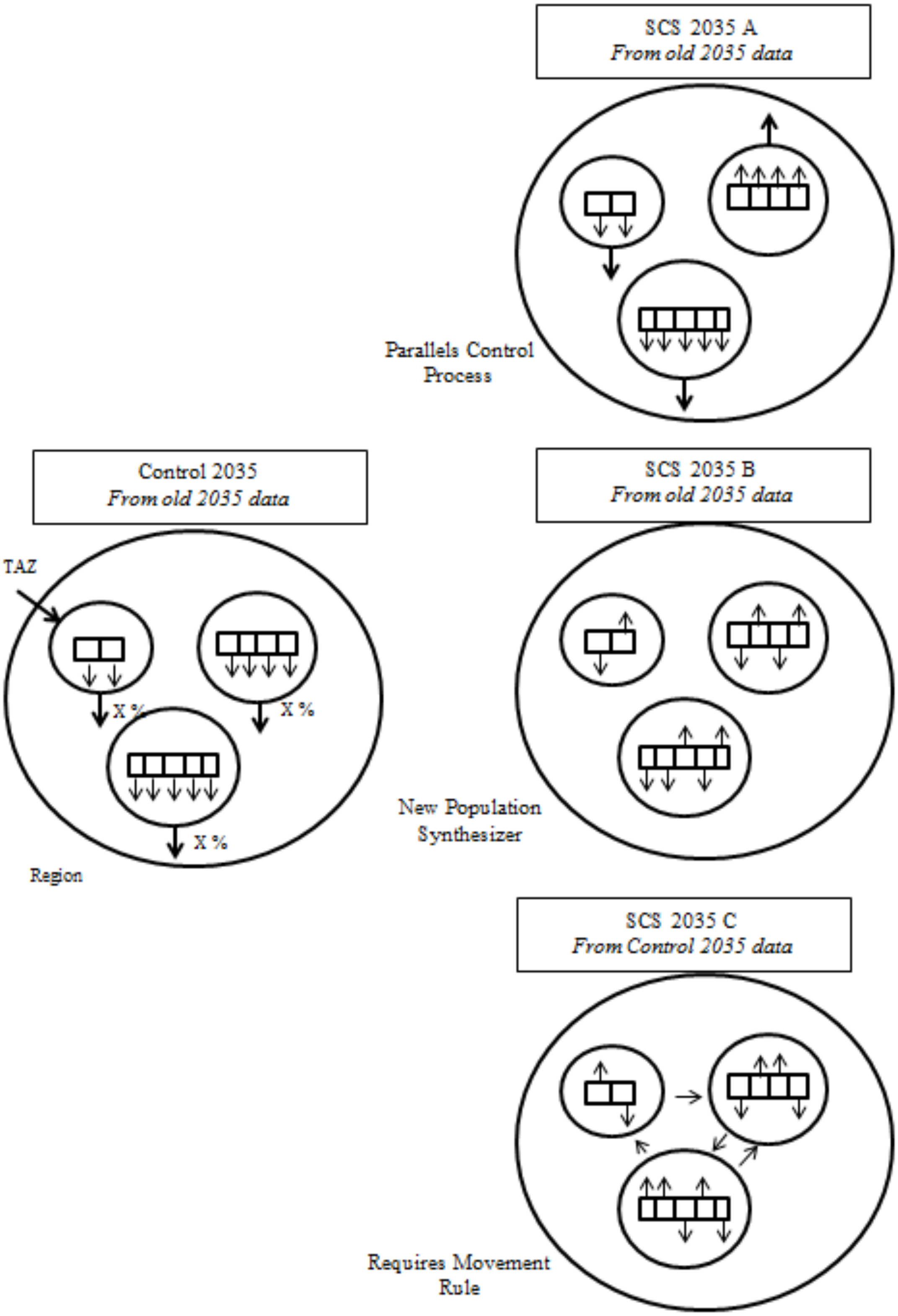

Figure 5-2: Assumptions used to simulate population changes in the creation of the modeling scenarios

The outer circles represented in Figure 5-2 represent regions, while the inner circles represent TAZs. The boxes inside the inner circles represent unique sample households drawn from the PUMS 5% sample. Accordingly, a homogeneous change to these households (either replication or deletion) will change the density, but not the demographic composition. The method for both the control (*left part of Figure 5-2*) and SCS – solution A (*top-right part of Figure 5-2*) uses this homogeneous modification to households within a TAZ, except that the solution A matches the forecasted SCS TAZ totals while the control matches the regional forecasted total by applying a consistent change to each TAZ. The SCS – solution B differs from these methods in that it would recreate the synthetic population by reapplying the population synthesizer program according to a new set of subpopulation forecasts. This process uses simulated annealing to add or remove households from TAZs to fit subpopulation forecasts. If consistent subpopulation forecasts are available, this method would match the new forecasted population in both magnitude and demographic composition. The SCS - solution C (*bottom-right part of Figure 5-2*) would reassign households from the synthetic population to other TAZs in the region to meet forecasted SCS TAZ totals. Depending on the method used, this could either change only the density of each TAZ or both the density and the demographic composition.

The latter two methods were initially pursued to modify regional synthetic populations to adhere to the new SCS forecasts due to their theoretical superiority. Unfortunately, these advantages also came with increased complexity: for instance, new sub-group data under the assumptions of the recent SCS plans could not be obtained in a consistent format from MPOs for this project. Similarly, the solution C would require the definition of a movement rule to define which households should be moved. Such an approach, which holds promise, was not developed as part of the current project, but may represent a potential extension for future extensions of the study.

Ultimately, population changes in the SCS scenario were simulated with the solution A: adding or subtracting households in the synthetic population for each TAZ to match the new targets forecasted by the local MPOs. For TAZs with substantial infill development, households were also drawn from neighboring TAZs. Total employment targets were also obtained from local MPOs and modifications to the target values for each job category were introduced to meet the total targets for each area. In order to account for omitted land use information for tier 2 MPOs, we used the California Department of Finance's county population forecasts and the California Department of Transportation (Caltrans) county employment forecasts to update land use targets. To mimic compact and infill development seen in the published SCSs, an 8% increase in urban population and employment was applied to all urban areas in tier 2 regions. Urban areas were defined by selecting TAZ with centroids within a certain radius of an area's major residential centers. The figure below shows an example of this process using a 2 mile buffer overlaid on the current urban structure of Bakersfield, CA.

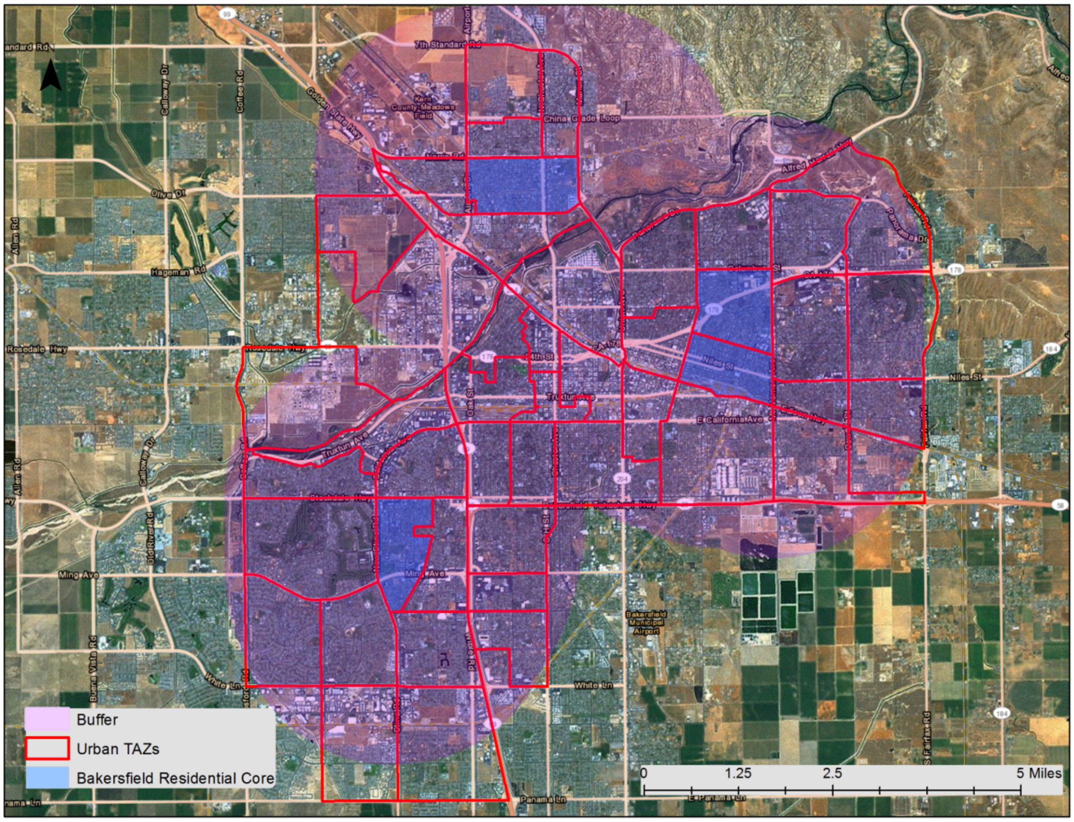

Figure 5-3: Smart Growth Scenario Applied to a Region without a Published or Draft SCS (Bakersfield, CA)

The urban population increase was coupled with a numerically equivalent decrease in suburban population in order to keep regional population constant between the SCS and the control scenarios. Additionally, 60% of the population shift was also applied to employment figures. This allowed a simulation of the potential impact of land use changes similar to those observed in the adopted SCSs from the MPOs in tier 1, also for areas where updated SCS plans are not available yet. It also extended the coverage of the study to the entire state. To isolate the effects of this extension of SCS policies on travel demand, one scenario was modeled using only data received by tier 1 regions. Figure 5-4 shows an example of the changes in land use between the SCS scenario and the control scenario (and their alignment with transit corridors) according to the local SCS for the SCAG (Los Angeles) region, the largest MPO in the state. The total regional population is numerically the same between the control and SCS scenarios; the map represents the spatial land use redistribution according to the adopted SCS.

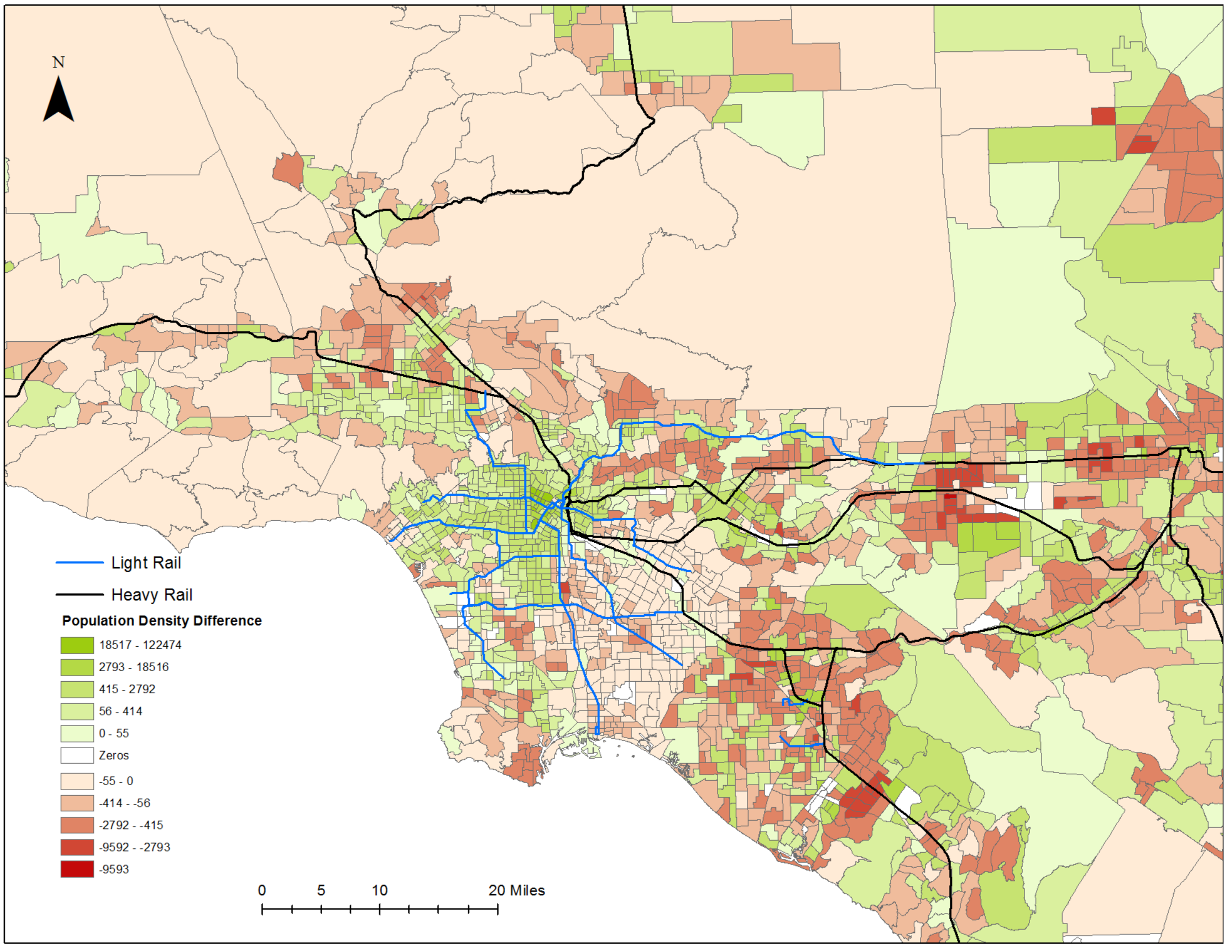

Figure 5-4: Population Density (persons/squared mile) Changes and Main Fixed Line Transit Corridors in the Los Angeles (Southern California Association of Government) Region

5.2.2 Transportation data

As part of the development of the SCSs, additional transit infrastructure and operational improvements were introduced in the future regional transportation plans for many regions. Many of these transit programs were not included in previous RTPs. Information on these new lines, stations, and headways were obtained from local MPOs, and were incorporated into the CSTDM transportation network and input files as part of the 2035 SCS scenario. In general, these data consisted of GIS files with geographically coded attributes. However, in the case of MTC, which uses the same CUBE-bases modeling platform of the CSTDM, their networks were directly imported in the CSTDM modeling framework. Table 5-4, Table 5-5 and Table 5-6 respectively outline the total miles in the transportation network in the SCS scenario, and the change from the control scenario by each transit type, for each region.

Table 5-4: Transit Lines (Miles, by Type) Explicitly Coded in the Control Scenario

		High Speed Rail	Intercity, Commuter, and Light Rail*	Bus Rapid Transit	Total (non-local) Transit Miles
MTC		281	1019	0	1300
	SACOG	0	313	0	313
	SANDAG	0	315	0	315
	SCAG	300	1120	0	1420
	SJV	323	524	0	847
	Central Coast	0	611	0	611
	Far North	0	346	0	346
	Mountain	0	0	0	0

Table 5-5: Transit Lines (Miles, by Type) Explicitly Coded in the SCS Scenario

		High Speed Rail	Intercity, Commuter, and Light Rail*	Bus Rapid Transit	Total (non-local) Transit Miles
MTC		281	1051	215	1546
	SACOG	0	313	225	538
	SANDAG	0	326	421	747
	SCAG	300	1317	38	1656
	SJV	323	524	0	847
	Central Coast	0	611	0	611
	Far North	0	346	0	346
	Mountain	0	0	0	0

Table 5-6: Changes in Miles of Transit Explicitly Coded between Scenarios

		High Speed Rail	Intercity, Commuter, and Light Rail*	Bus Rapid Transit	Total (non-local) Transit Miles
MTC		0%	3%	N/A	19%
	SACOG	N/A	0%	N/A	72%
	SANDAG	N/A	3%	N/A	137%
	SCAG	0%	18%	N/A	17%
	SJV	0%	0%	N/A	0%
	Central Coast	N/A	0%	N/A	0%
	Far North	N/A	0%	N/A	0%
	Mountain	N/A	N/A	N/A	N/A

Local Bus

Updated information on the level of service (LOS) for local transit, which is a modeling input used in the synthetic approach to model local transit services in the CSTDM was also determined for all major catchment areas in the state by using revised estimates of population and revenue miles obtained from local MPOs.

As defined earlier, the CSTDM uses a synthetic network to simulate local bus travel. The bus LOS used in the 2035 control scenario were calculated based on 2009 annual revenue miles and population and assumed to vary constantly with population into 2035. For the 2035 SCS scenario, modifications were made to the bus LOS of each catchment area based on the information available. In general, tier 1 regions provided ArcGIS line files of bus lines with information on location and frequency of each route included in the SCS. In order to calculate the annual revenue miles for each route from this piece of information the following approximated equation was used to compute the annual revenue miles served by local buses:

$$Route\ Annual\ Miles = Length \times Frequency \times {}^{6days}/_{week} \times 52weeks$$

Care was taken to double the length of segments when routes traveled them twice (for example, as an effect of two-way lines operating on the same links). An approximation of “6 days per week” was used in the equation above to capture weekend service while accounting for the usually lower service levels seen on weekends. These estimates for route based annual revenue miles were then spatially joined to the catchment area in which they were located. If a route was located in multiple service areas only those portions within a particular area were allocated to that service area. At the end of this process the sum of annual revenue miles was divided by the projected 2035 population as defined in the SCS scenario for each catchment area. An example is shown in Figure 5-5 below.

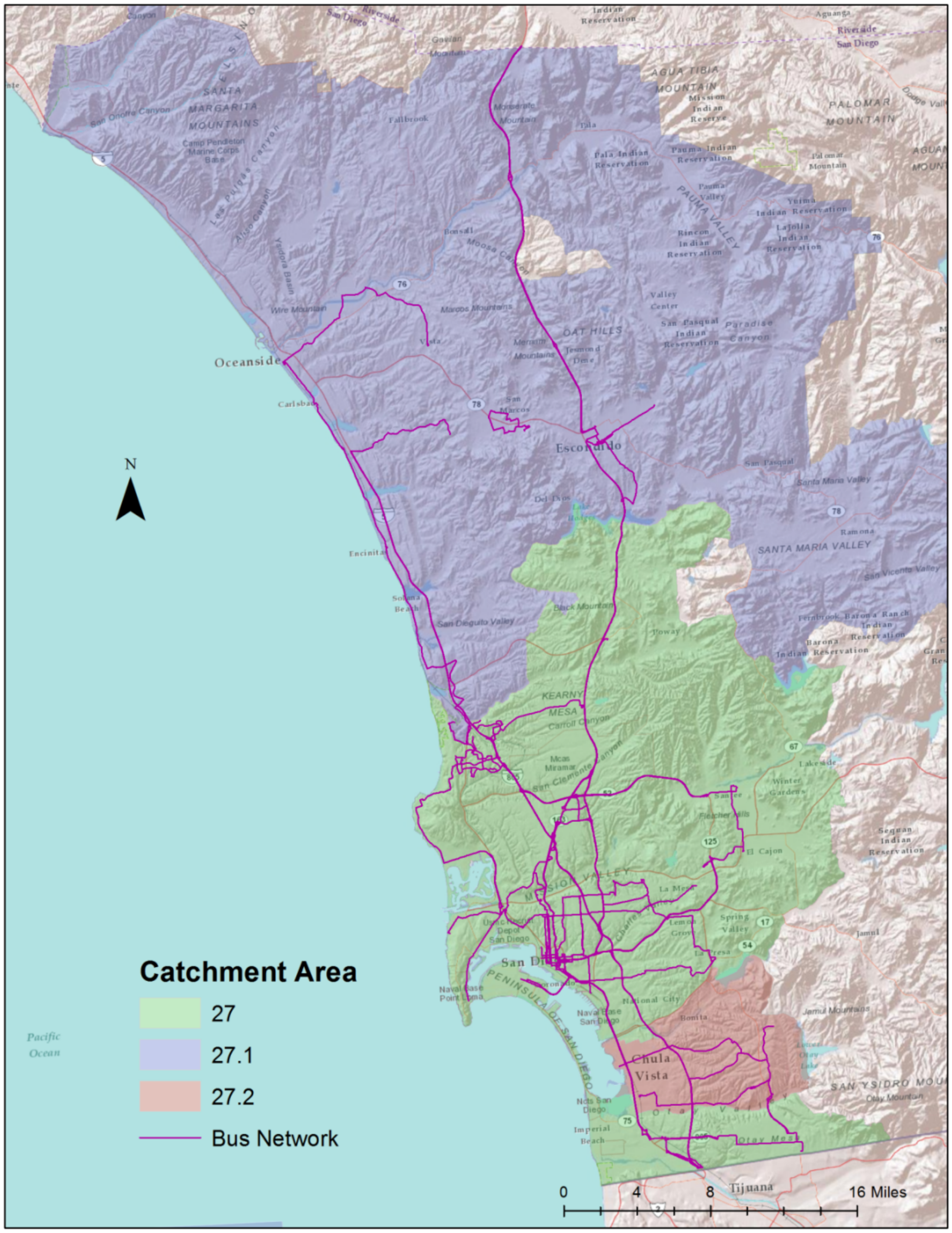

Figure 5-5: Catchment Area (with Identification of Service and Transfer Areas) with Bus Network for the SANDAG Region

The MTC region was handled differently, due to the different data format received from this MPO. In their case, an estimate for the total revenue hours was obtained for 2035 according to SCS adjustments and compared to the revenue hours reported in their region in 2009. In the final model scenarios this estimate was enhanced using operator specified route level data obtained from MTC. For tier 2 regions, information was not provided for future transit services. For tier 2 regions that did not have any data available, an alternative approach was adopted. Based on transit improvements in each of the tier 1 regions, a 25% improvement in bus LOS was used for tier 2 regions. It should be noted that no catchment areas were extended; instead improvements were made on the quality of existing catchment areas as already defined in the 2035 control scenario. The table below shows the LOS measures in the Control and SCS scenarios.

Table 5-7: Comparison of Bus Level of Service (LOS)

Transfer Area	Service Area	Agency	Level of Service (LOS)	SCS LOS
1	1	Del Norte County Public Transit	200.0	150.0
2	2	Humboldt Transit Authority	200.0	150.0
3	3	Lassen Transit Service Agency	200.0	150.0
4	4	Redding Area Bus Authority	186.5	139.9
5	5	Butte County Transit, Chico Area Transit, Oroville Area Transit	187.8	140.9
6	6	Gold Country Stage (Nevada County)	200.0	150.0
7	7	Sacramento Regional Transit District	127.8	114.2
	7.1	Yolobus, Unitrans	59.2	59.2
	7.2	Placer County Transit, Roseville Transit	128.9	128.9
	7.3	El Dorado County Transit Authority	200.0	200
8	8	Sonoma County Transit, Santa Rosa CityBus, Petaluma Transit	151.2	151.2
	8.1	San Mateo County Transit District (SamTrans)	95.5	89.4
	8.2	San Francisco Municipal Railways (Muni)	39.3	39.3
	8.3	Alameda-Contra Costa Transit District (AC Transit)	63.2	63.2
	8.4	Santa Clara Valley Transportation Authority (VTA)	103.2	103.2
	8.5	Golden Gate Transportation District	46.1	46.1
	8.6	Central Contra Costa Transit Authority, Eastern Contra Costa Transit Authority, Western Contra Costa Transit Authority	106.8	106.8
	8.7	Livermore / Amador Valley Transit Authority	86.5	86.5
	8.8	Vallejo Transit, Fairfield and Suisun Transit, Benicia Breeze	95.8	95.8
	8.9	The VINE (Napa County)	120.6	120.6
9	9	San Joaquin Regional Transit District	79.3	59.5
10	10	Modesto Area Express	187.9	140.9
11	11	Merced County Transit, BLAST, DART	123.8	92.9
12	12	Fresno Area Express	127.0	95.3
13	13	Kings County Area Public Transit Agency	123.1	92.3
14	14	Visalia City Coach, Porterville COLT	104.7	78.5
15	15	Golden Empire Transit (Kern County)	184.8	138.6
16	16	Amador Regional Transit System	200.0	150.0
17	17	Santa Cruz Metropolitan Transit District	78.2	58.7
18	18	Monterey-Salinas Transit	98.9	74.2
19	19	SLO Transit (San Luis Obispo)	175.4	131.6

20	20	Santa Barbara Metropolitan Transit District	68.8	38.5
21	21	Gold Coast Transit (Western Ventura County)	200.0	160.1
22	22	Thousand Oaks Transit, Simi Valley Transit	200.0	166.9
23	23	Los Angeles County Metropolitan Transportation Authority (LA Metro) and various minor LA area operators (Montebello, Culver City, Norwalk, Lompoc, Redondo Beach, Commerce, Corona, Laguna Beach)	49.5	44.9
	23.1	Omnitrans (San Bernadino County)	149.0	104.6
	23.2	Orange County Transportation Authority	112.9	85.9
	23.3	Riverside Transit Agency	134.2	134.2
	23.4	Long Beach Transit	91.4	31.7
	23.5	Santa Monica's Big Blue Bus	70.5	15.8
	23.6	Foothills Transit	77.3	55.7
	23.7	Antelope Valley Transit Authority	119.0	113.2
	23.8	Santa Clarita Transit	200.0	48.5
	23.9	Torrance Transit System, Gardena Municipal Bus Lines	93.8	26.0
24	24	Victor Valley Transit Authority	192.0	192.0
25	25	SunLine Transit Agency (Palm Springs / Coachella Valley)	149.0	149.0
27	27	San Diego Metropolitan Transit System	75.6	73.4
	27.1	North County Transit District	111.7	109.8
	27.2	Chula Vista Transit	138.4	87.0
28	28	Santa Maria Area Transit	138.4	77.7
29	29	Yuba-Sutter Transit Authority	119.1	119.1
30	30	Imperial Valley Transit	178.7	178.7
31	31	Tahoe Area Regional Transit	200.0	150.0
32	32	Trinity County Transit	200.0	150.0

Light Rail Transit

Light rail transit improvements were added explicitly in the statewide network and line files. These modifications included improvements in frequency, increased stops along the route, extension of an existing route, addition of a new route, or a combination. This information was available and coded for only tier 1 regions. For all tier 1 MPOs except MTC, GIS line files were obtained and used to code light rail lines, stops, and service first seen in the SCSs. Changes made in MTC were made based on visual inspection of SCS documentation and the transit network provided in a CUBE format.

In the CSTDM framework, all links established on or before the year modeled are collected and used in each scenario. The map in Figure 5-6 shows these changes throughout the state. Although it does not appear on the map because it was previously planned, SANDAG did move up the completion date of one of its light rail lines in their SCS making it viable by 2035.

Figure 5-6: New rail projects introduced with the updated RTP/SCS plans

Bus Rapid Transit

Bus rapid transit (BRT) was also added to the CSTDM as part of this project. This represents a major update for this modeling framework, as BRT lines were not included in earlier modeling studies using the CSTDM. The BRT additions were coded in the same way new light rail routes were coded. In SCAG, BRT lines were coded as distinct new lines with associated travel times and headways. SANDAG only distributed interstation distance and speed, therefore interstation time was computed from these measures. MTC used a different system by adding dedicated lanes to their roadway network and providing a time benefit to transit lines that traversed the dedicated lanes. To transfer this information to the CSTDM, line placement and time was derived from the highway network where BRT facilities existed, and headways were determined from the lines that traversed them. Unlike other MPOs, the locations of BRT stations in the

SACOG region have not been defined. Therefore typical station location and interstation travel time were inferred from information from other MPOs. The projected speeds of BRT from SCAG and SANDAG are 20-25 mph in urban areas up to 65 on the major freeways. In the SACOG region, a speed of 25 mph was used in downtown and 35 mph elsewhere.

The BRT additions for each region vary greatly across the state. The area with the most extensive current BRT network, SCAG, largely plans to replace segments of BRT with light rail by 2035. Areas with little change in light rail plans pre- and post-SCS, including SANDAG and SACOG, seem to compensate with massive BRT investment. MTC splits these two approaches with a moderate amount of BRT infrastructure planned. Figure 5-7 outlines the BRT lines coded in the CSTDM SCS scenario.

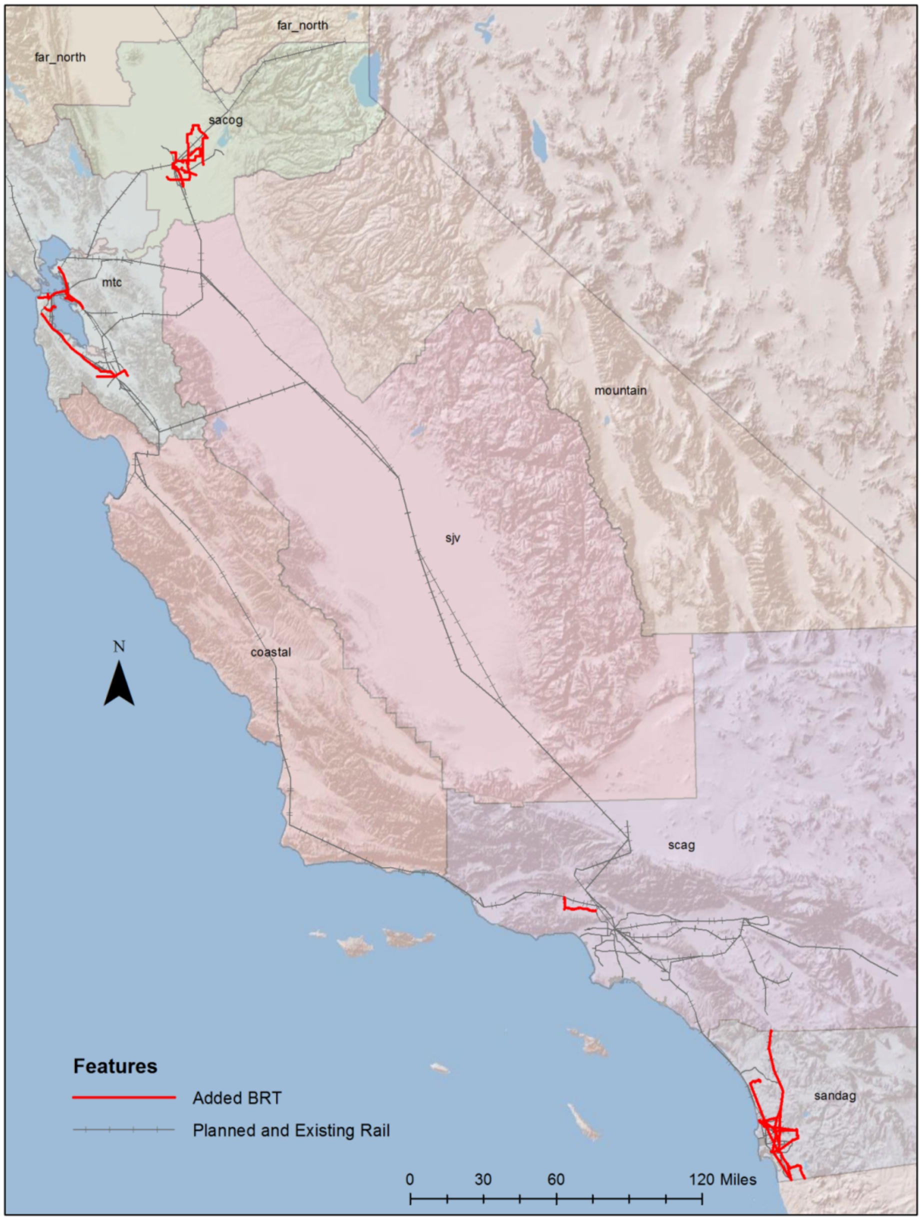

Figure 5-7: New BRT projects introduced in the SCS scenario

5.3 Regional Inputs

The following sections summarize the major regional SCS changes contained in the SCS modeling scenario that was modeled in the CSTDM modeling framework (compared to the 2035 control scenario).

5.3.1 Southern California (SCAG)

Figure 5-8 shows the main transit extensions and major changes in the distribution of population in the Southern California region from the control to SCS scenario. Several transit lines were extended or added in Los Angeles County. High population density increases can be seen in central Los Angeles, with smaller pockets of increasing and decreasing density spaced throughout the region.

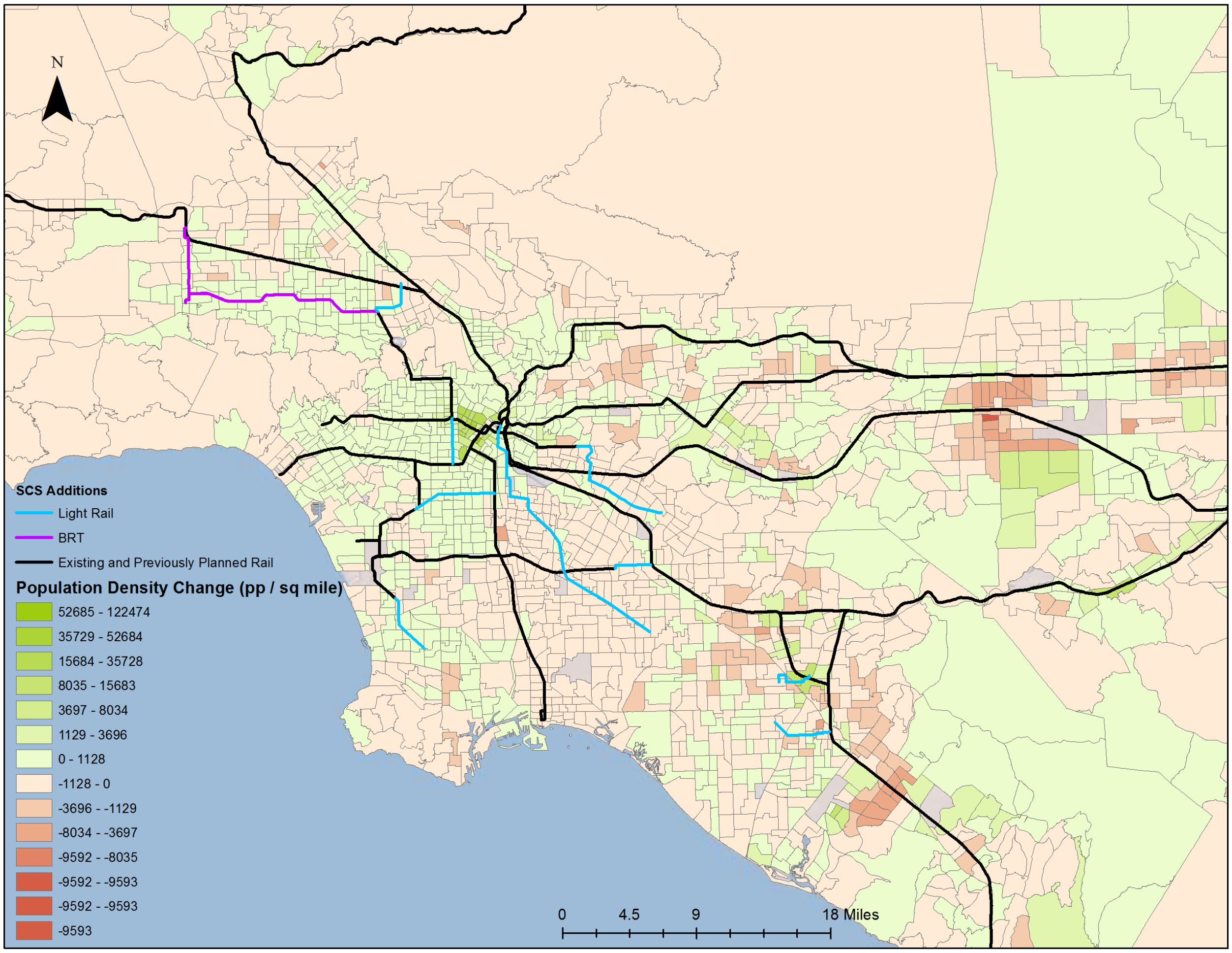

Figure 5-8: Changes in Population Density and Main Transit Lines from the Control to the SCS Scenario in the SCAG Region

5.3.2 Sacramento (SACOG)

In the greater Sacramento area, huge investments in BRT have been planned. Few general land use patterns can be distinguished, with Figure 5-9 summarizing the overall changes in population density across the region.

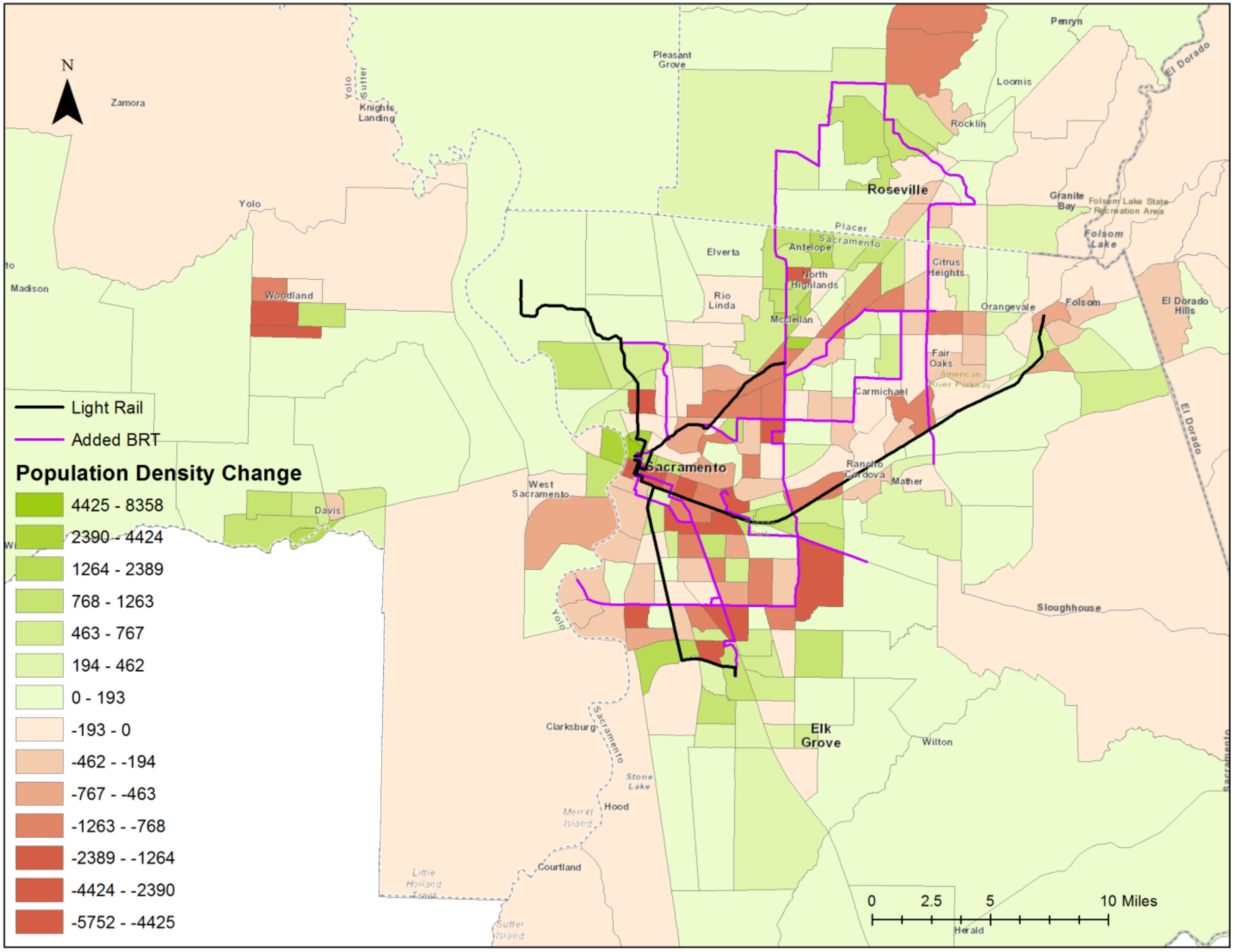

Figure 5-9: Changes in Population Density and Main Transit Lines from the Control to the SCS Scenario in the SACOG Region

5.3.3 San Diego (SANDAG)

Land use changes in San Diego County varied in a similar way to the Sacramento region. High changes are seen in the more heavily populated areas of San Diego and Escondido. An extensive Bus Rapid Transit line is added to connect many of the urban centers along major highway links.

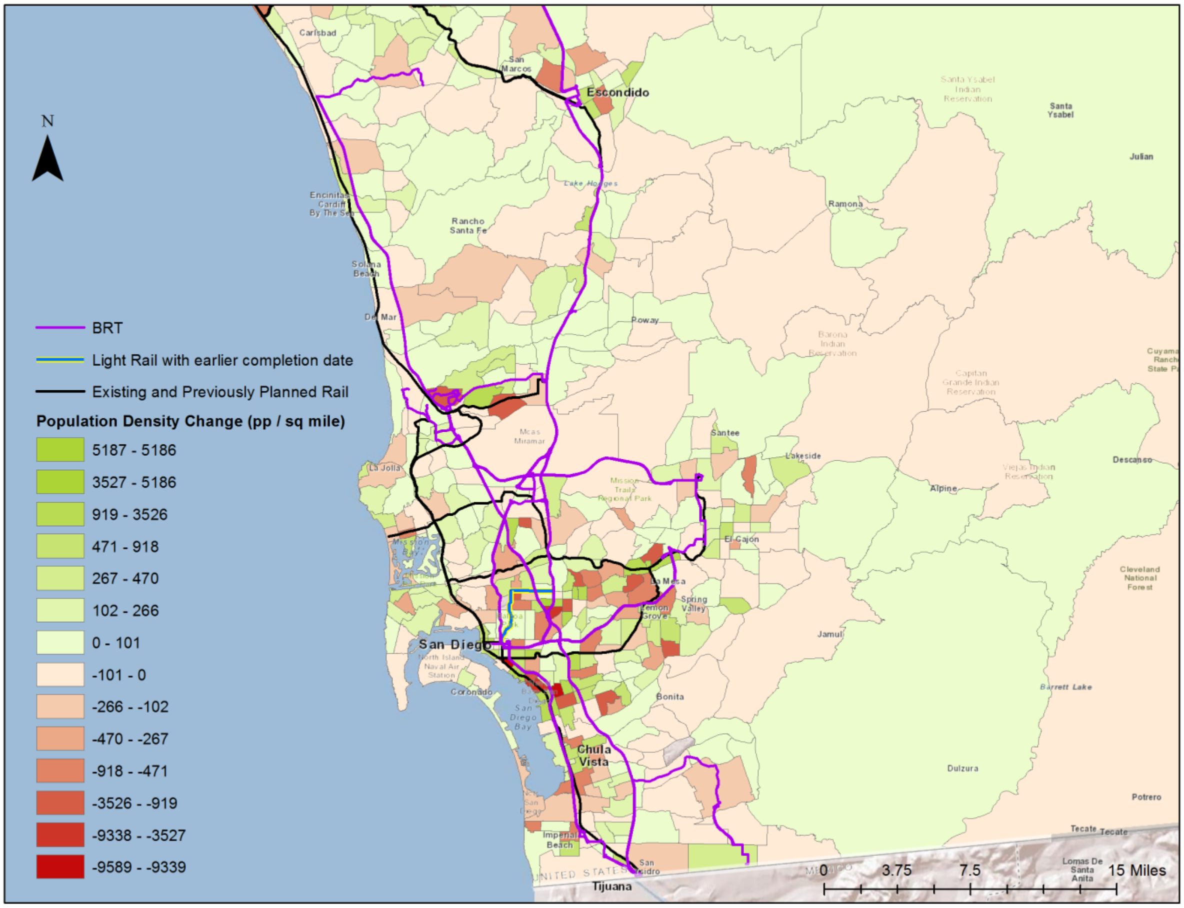

Figure 5-10: Changes in Population Density and Main Transit Lines from the Control to the SCS Scenario in the SANDAG Region

5.3.4 The Bay Area (MTC)

The Bay Area sees heavy population density growth in downtown San Francisco and along transit connected urban corridors. One Bay Area Rapid Transit (BART) line is extended South into San Jose, while several BRT lines fill in existing rail gaps and overlap the commuter rail services between San Francisco and San Jose. Additional lines are added to the MUNI urban rail system.

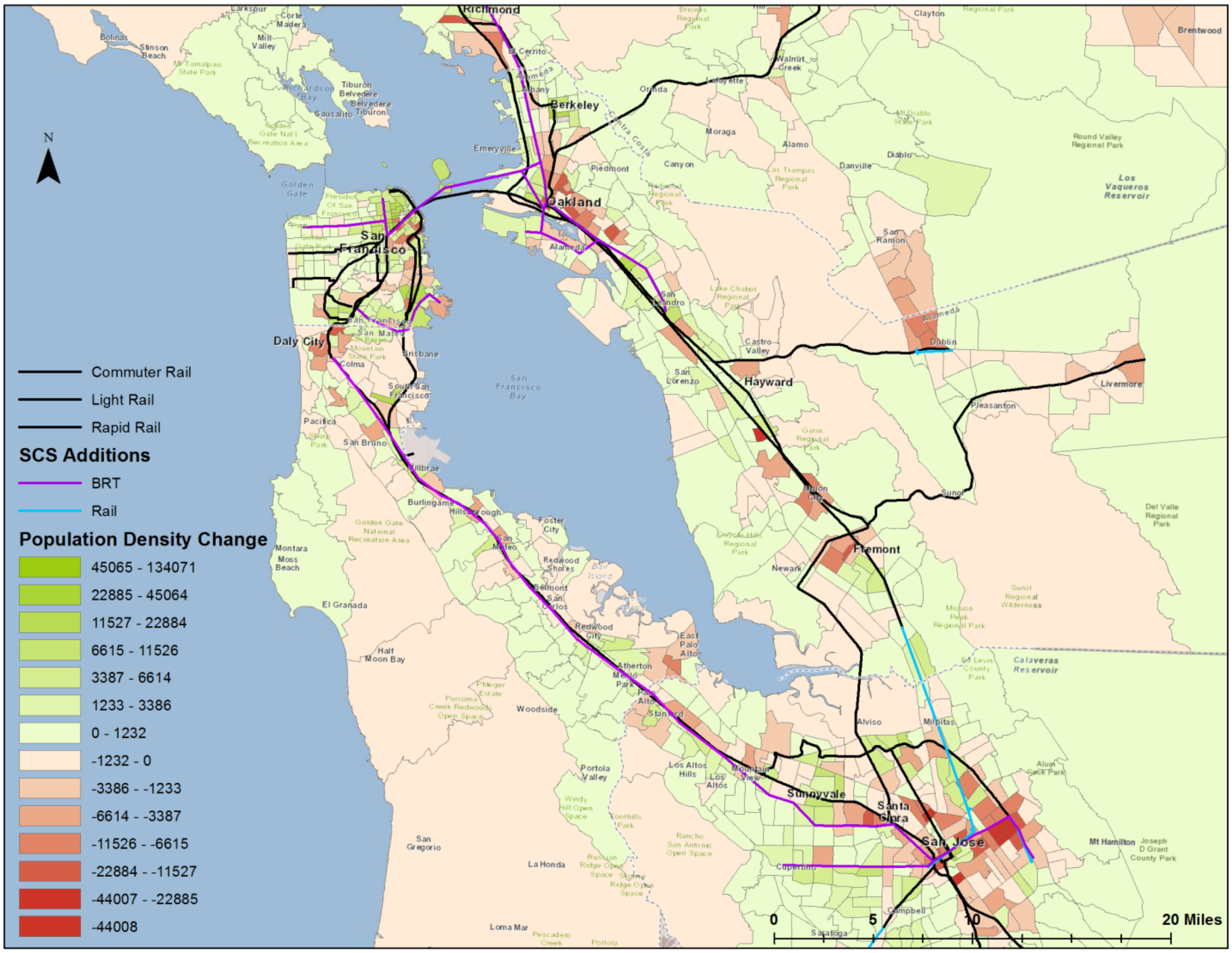

Figure 5-11: Changes in Population and Main Transit Lines from the Control to the SCS Scenario in the MTC Region

5.3.5 Santa Barbara (SBCAG)

In Santa Barbara County, the cities of Santa Maria, Isla Vista, and Santa Barbara see scattered increases in density while the rest of the region decreases compared to the control scenario. Smaller local bus routes are added to the region and incorporated into the bus LOS calculation.

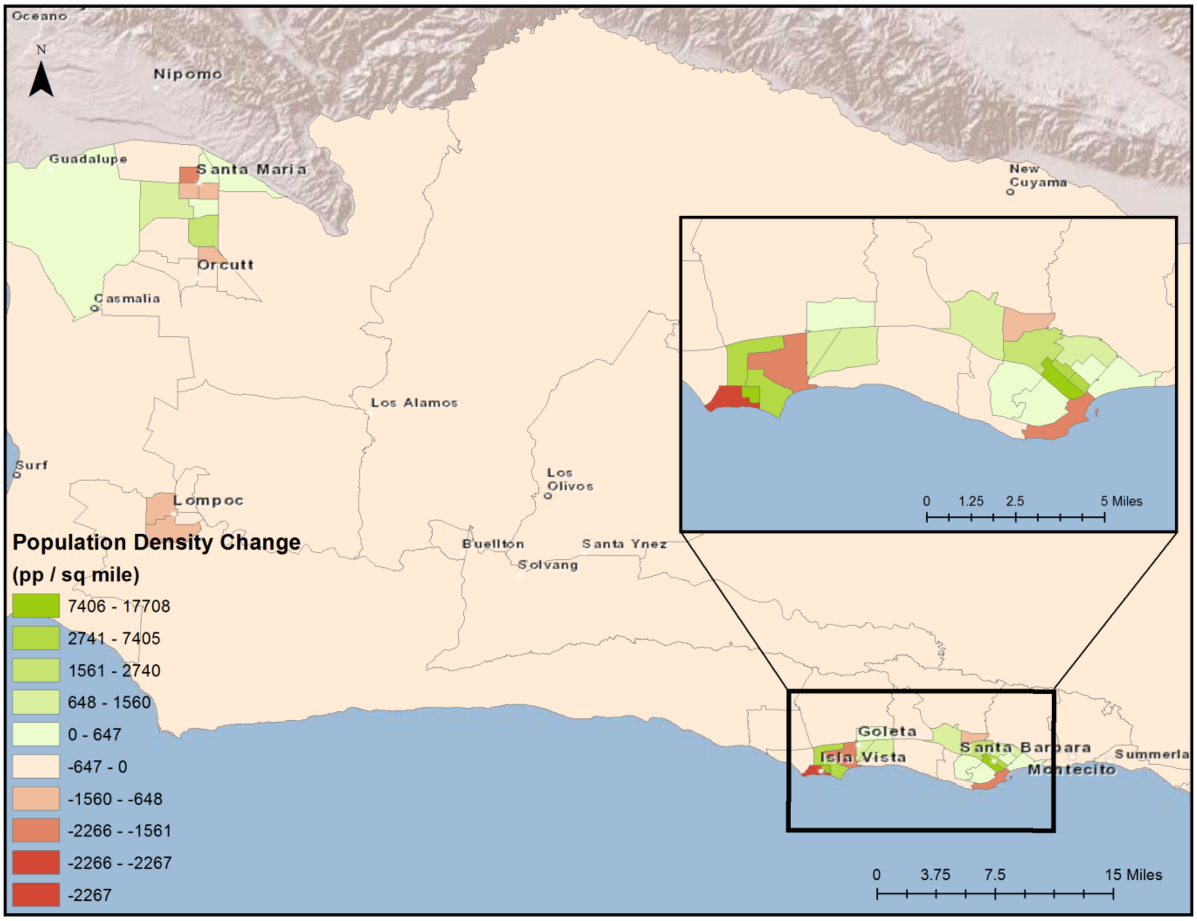

Figure 5-12: Changes in Population Density from the Control to the SCS Scenario in the SBCAG Region

5.3.6 Butte County (BCAG)

Compared to the control scenario, population density in urban areas in Butte County actually decreases according to their SCS. This may be due to the relative size of TAZs in the CSTDM, as well as to the economic recession adversely affecting urban areas to a greater extent than rural areas. As with Santa Barbara County, bus improvements were incorporated into the bus LOS for urban areas.

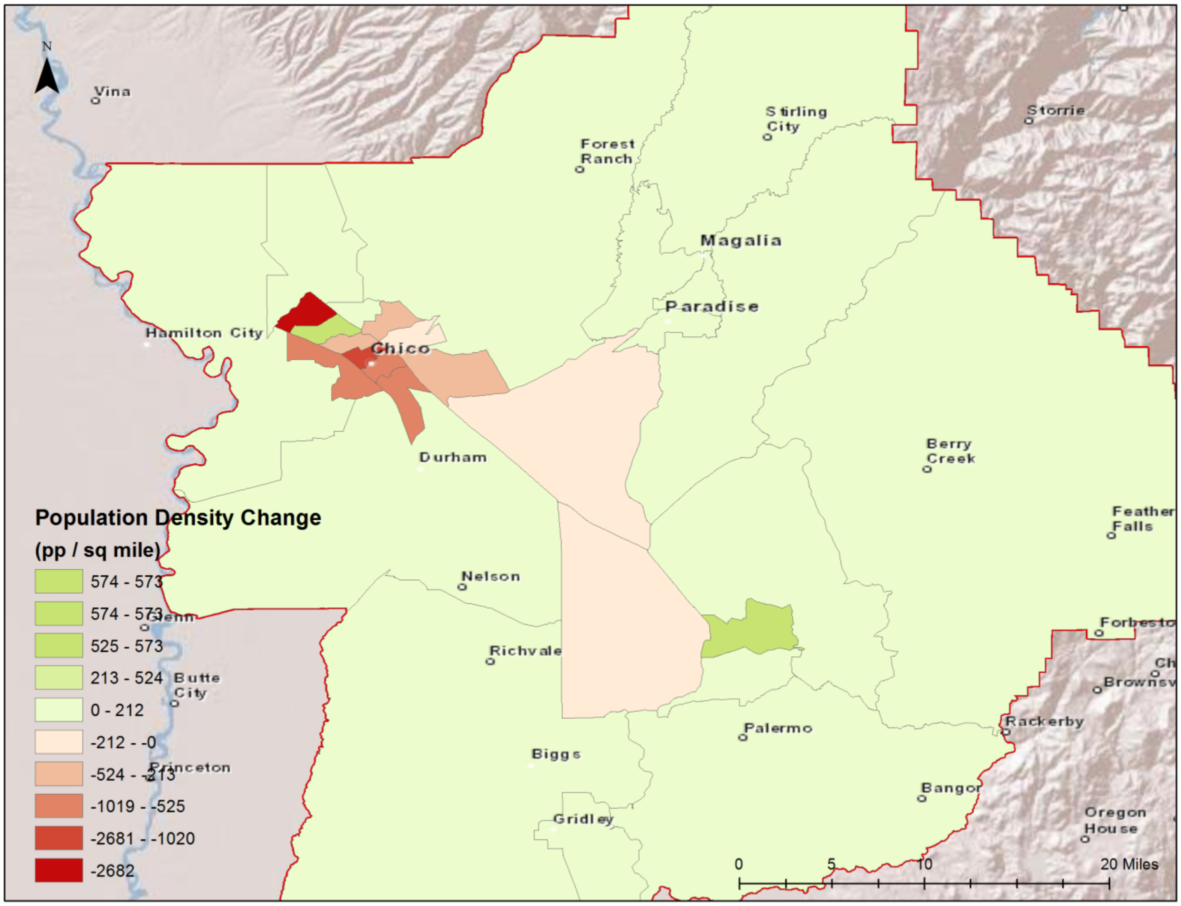

Figure 5-13: Changes in Population Density from the Control to the SCS Scenario in the BCAG Region

5.3.7 Tahoe (TMPO)

Increases in density are seen in South Lake Tahoe, and slight changes are seen in other lakeside TAZs. However, figures obtained for population and employment in the Tahoe region from planning documents are greater than those obtained in this study after their SCS was published, probably due to changes in the way data were reported. Therefore it should be noted that the changes modeled in this region may not completely reflect planning changes by TMPO, but might be due to inconsistencies in the available data used in the modeling study.

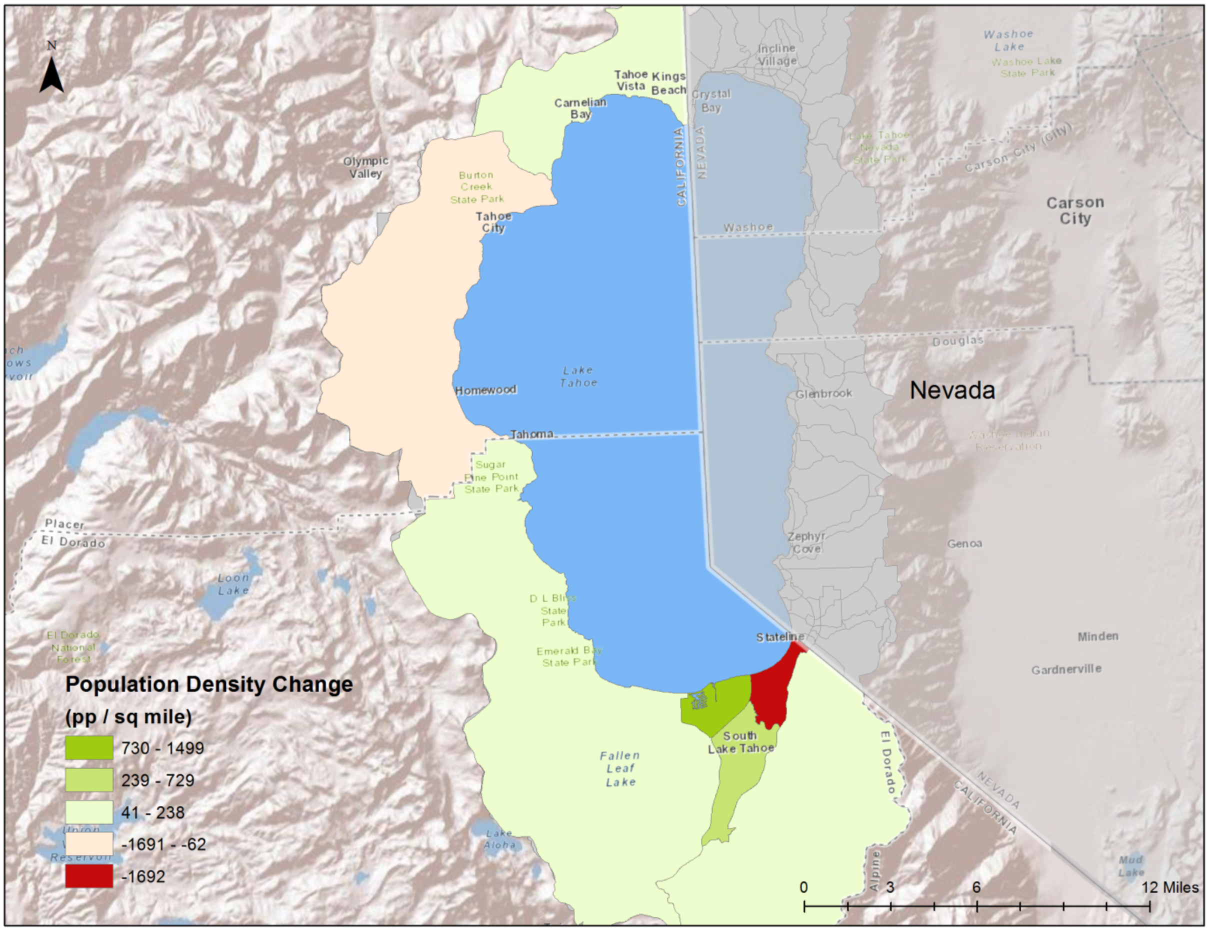

Figure 5-14: Changes in Population Density from the Control to the SCS Scenario in the TMPO Region

6. Modeling Results

6.1 Statewide analysis

Table 6-1 summarizes the regional changes in population and employment density in TAZs within a half mile of a transit stop in the various regions of California. The numbers reported are the combined result of policies of infill development, transit oriented development, and transit access improvement. The results in the table focus on the main fixed transit lines including BRT. Therefore, the percentage of regional population in transit zones indicates the proportion of a region's population that has close access to light or heavy rail transit. In several cases, reductions in the density around transit corridors are due to an extension of the rail network to lower density areas (which previously were not reached by transit), which reduced the average population density in the more easily transit-accessible area.

Table 6-1: Regional Density Changes of Main Transit Areas in SCS and Control Scenario

Region	Transit Area (sq. miles)		Population in Transit Zone (10,000s)		Employment in Transit Zone (10,000s)		Percent of Regional Population in Transit Zones		Population Density Difference		Employment Density Difference	
	Control	SCS	Control	SCS	Control	SCS	Control	SCS	Absolute	Percent	Absolute	Percent
MTC	506	567	449	526	292	319	50%	59%	400	4.5%	(149)	-2.6%
SACOG	146	269	79	142	52	78	25%	45%	(142)	-2.6%	(664)	-18.6%
SANDAG	235	353	161	220	95	124	40%	55%	(656)	-9.5%	(560)	-13.8%
SCAG	641	762	473	633	312	374	21%	29%	928	12.6%	46	0.9%
Rest of California	159	159	63	65	34	35	7%	7%	97	2.4%	10	0.5%

Regional land use and transportation policies, as those contained in the RTPs/SCSs, have the potential to affect the use of transportation at local, regional and interregional/long-distance level. Table 6-2 summarizes the short distance personal VMT and VMT per capita forecasted for each scenario. Considerable changes are found in VMT per capita in MTC, and more modest improvements are found in the SCAG, SACOG and other regions.

Table 6-2: Regional Short Distance Passenger VMT

Region	Population (10,000s)		VMT (10,000s)		VMT/Capita		
	Control	*SCS*	*Control*	*SCS*	*Control*	*SCS*	% Change
MTC	894	894	12,570	11,355	14.1	12.7	-9.7%
SACOG	313	313	4,918	4,870	15.7	15.6	-1.0%
SANDAG	402	402	6,728	6,689	16.7	16.6	-0.6%
SCAG	2,209	2,209	35,102	34,577	15.9	15.7	-1.5%
SJV	619	619	8,203	8,112	13.2	13.1	-1.1%
Rest of California	325	325	4,843	4,752	14.9	14.6	-1.9%
Total	4,763	4,763	72,364	70,356	15.2	14.8	-2.8%

Overall, the magnitude of the changes in VMT/capita seem to be larger in areas with higher increases in urban densities, better housing/employment balance and an extension of areas served by high-quality transit services. As the case of MTC highlights, these travel outcomes also depend on a number of factors like improved bus service and to a large extent general land use distribution and employment/housing balance.

Table 6-3 outlines the mode shares (percentage of the number of trips) for short distance personal travel by region. These results indicate that a large portion of the VMT reduction in the MTC region is associated with a substantial increase in transit ridership. An increase in transit and active transport is also observed in SCAG as well as, more marginally, in other regions. The percentage of trips made by public transportation in the SCAG region is still rather low compared to other US metropolitan areas, thus highlighting the difficulty associated with changing travel behavior in an area that has encouraged car mobility for many decades. Yet the changes in VMT and transit share in SCAG are particularly important considering the size of this region, and its weight on total travel in California. In addition, they are the results of the important policies developed in the area: SCAG has the highest population density change in transit areas (Table 6-1) and a fairly high increase in employment density. Large investments have been planned to support the expansion of public transportation, in particular in the central areas near the City of Los Angeles and, to a lesser extent, also in the rest of the region, recently coupled with a strong increase in densities in more central areas (cf. **Figure** 5-4).

Table 6-3: Regional Short Distance Personal Mode Share

Region	Trips (10,000s)		Auto Share		Transit Share		Active Transport Share	
	Control	SCS	Control	SCS	Control	SCS	Control	SCS
MTC	2,734	2,719	86.5%	80.5%	6.0%	11.1%	7.5%	8.4%
SACOG	909	908	90.9%	90.9%	3.6%	3.7%	5.4%	5.5%
SANDAG	1,241	1,241	90.3%	90.2%	3.9%	4.0%	5.7%	5.7%
SCAG	6,396	6,385	89.4%	88.6%	3.3%	3.8%	7.3%	7.6%
SJV	1,790	1,789	89.0%	88.7%	3.9%	4.2%	7.0%	7.1%
Rest of California	950	949	91.1%	90.6%	3.3%	3.6%	5.6%	5.8%
Total	14,018	13,992	89.08%	87.5%	4.0%	5.3%	6.9%	7.3%

In addition to considering the regional effects of the proposed policies, the application of the CSTDM model to these scenarios allows us to analyze the expected impact of the proposed policies on interregional travel. Table 6-4 summarizes the percent change in VMT (and in the number of vehicle trips, in parentheses) between adjacent regions in the state. Overall, the effects of the largely regionally-based SCS policies on interregional VMT seem to correlate well with the forecasted regional effects. The largest changes are observed to/from MTC, following a trend similar to the short distance changes in the region. Interregional vehicle trips and miles traveled between SACOG and SJV are expected to increase, probably as an effect of the increased interactions associated with the land use development in SJV, which might provide convenient residential location in the SJV for workers employed in/traveling regularly to/from the SACOG region. Trips from SCAG to SANDAG are also expected to increase, although this marginal increase is considered to be within the margin of error of the model.

Table 6-4: Change in Regional Interregional Flows (SCS vs. Control Scenarios)[1]

Region	MTC	SACOG	SJV	SCAG	SANDAG
MTC	-8.0 (*-9.6*)%	-4.2 (*-3.5*)%	-1.3 (*-3.5*)%		
SACOG	-3.3 (*-3.4*)%	-0.6 (*0.0*)%	1.0 (*0.8*)%		
SJV	-2.6 (*-3.9*)%	0.8 (*1.1*)%	-0.8 (*-0.7*)%	0.2 (*-1.4*)%	
SCAG			-1.1 (*-1.9*)%	-1.4 (*-1.2*)%	0.5 (*0.3*)%
SANDAG				-0.1 (*-0.6*)%	-0.3 (*0.1*)%

[1] Percentage change in interregional VMT (percentage change in the number of interregional trips is reported in parentheses)

The comparison of the results from the two scenarios provides information on the expected changes prompted by regional plans throughout the state and partially due to SB 375. Still, a large part of the potential success of these policies actually depends on the way they will be implemented. The development of Sustainable Communities Strategies is a delicate process that involves many considerations in terms of environmental, social and economic impacts of the proposed policies and plans. In addition, successful SCSs require the cooperation of regional and local authorities for a full coordination of actions and proper implementation, at the local level, of the proposed policies. While some bold policies have been proposed in limited areas (including cordon pricing in San Francisco), the development of the SCSs has generally not been coupled with additional economic tools (e.g. pricing, gas taxes or incentive programs). According to several researchers, this might significantly reduce the potential results from the adoption of these strategies, which might be below expectations (Chatman 2008, Heres-Del-Valle and Niemeier 2011).

6.2 Analysis of Synergies and Discussion of Results

Integrated land use and transportation planning was expressed as a central pillar of the Sustainable Community Strategies, as described in Section 4 article b 4 in SB 375:

> *"The sustainable communities strategy…shall set forth a forecasted development pattern for the region, which, when integrated with the transportation network, and other transportation measures and policies, will reduce the greenhouse gas emissions from automobiles and light trucks to achieve, if there is a feasible way to do so, the greenhouse gas emission reduction targets approved by the state board."*

To test the value of the integrated policy packages and to discuss the corresponding partial effects generated by isolated policies, a transit improvement scenario and a land use policy scenario were also modeled separately. These two scenarios are comprised of all policies of their respective type throughout the state, and can be thought of as two *subsets* that make up the above described SCS scenario. When analyzed separately, conclusions can be made about the impact of land use and transportation policies in isolation, when compared to the control scenario (business as usual). Table 6-5 below reports the comparisons for short distance passenger VMT per capita changes compared to the control scenario. When comparing the impacts of the transportation and land use policies on VMT per capita reductions it is evident that land use changes account for the vast majority of changes in most regions.

However, the contribution of each type of policy can vary dramatically for different regions. Land use policies in isolation are expected to be responsible for reductions in VMT of at least 48% of the total VMT predicted summing the effects of the separate land use and transportation policy scenario (summed as the effects were perfectly addictive). Much higher percentages are forecasted in other regions, where the impact of land use policies is clearly predominant. In one case, in the SANDAG region, the transit improvements if implemented in isolations would not be able to generate reductions in VMT/Capita. However, when comparing the outcomes of the combined SCS scenario with the sum of the individual effects from the partial scenarios, many regions show relevant synergistic effects. The analysis of the figures from Table 6-5 confirms the importance of the coordination of land use and transportation policies, which in most cases bolster VMT (and GHG) reductions from transportation beyond what could be achieved if these policies were implemented without coordination.

Table 6-5: Changes in Short Distance Passenger VMT/Capita (Compared to the Control Scenario) in the Combined SCS Scenario, Transit Improvement (only) Scenario, and Land Use Change (only) Scenario

	SCS Transit Scenario		SCS Land Use Scenario		Transit + Land Use (Sum)[1]	SCS Scenario		
Region	VMT/ Capita	% of Sum of Reduction[2]	VMT/ Capita	% of Sum of Reduction[2]	VMT/ Capita	VMT/ Capita	% of Sum of Reduction[3]	Synergies
MTC	0.0%	0.2%	-9.4%	99.8%	-9.4%	-9.7%	102.9%	+
SACOG	-0.2%	15.5%	-0.9%	84.5%	-1.0%	-1.0%	94.9%	-
SANDAG	0.0%	-5.2%	-0.4%	105.2%	-0.4%	-0.6%	146.6%	++
SCAG	-0.7%	48.6%	-0.7%	51.4%	-1.4%	-1.5%	102.9%	+
SJV	-0.7%	51.9%	-0.6%	48.1%	-1.3%	-1.1%	82.4%	-
Rest	-0.4%	21.8%	-1.5%	78.2%	-2.0%	-1.9%	95.7%	-
Total	-0.5%	16.9%	-2.3%	83.1%	-2.7%	-2.8%	101.8%	+

[1] Sum of the reductions in VMT/Capita from the isolated *Transit* and *Land Use* scenarios, computed to allow analysis of synergies through the comparison with the combined SCS scenario;

[2] These columns report the change in VMT/Capita measured in each partial (*Transit* or *Land Use*, as a percentage of the sum of the effects from the isolated transit and land use scenario.

[3] This column reports the change in VMT/Capita measured in the combined SCS scenario, as a percentage of the sum of the effects from the isolated transit and land use scenario (for purposes of evaluation of policy synergies).

Further results, such as the interregional flows, were also analyzed for the separated policy scenarios. Results for the transit and land use scenarios are shown below in Table 6-6 and Table 6-7, respectively. Similar to the results for the interregional travel from the combines 2035 SCS scenario contained in Table 6.4 (as shown previously), the first number in each cell represents the change in VMT from interregional travel, while the numbers in parentheses show the changes in the number of interregional vehicle trips.

Table 6-6: Change in Regional Interregional Flows (Transit SCS vs. Control Scenarios)

Region	MTC	SACOG	SJV	SCAG	SANDAG
MTC	0.1 (-0.2)%	0.5 (0.0)%	-2.5 (-3.6)%		
SACOG	0.5 (0.1)%	-0.1 (-0.1)%	0.0 (-0.1)%		
SJV	-5.1 (-3.9)%	0.0 (-0.1)%	-0.4 (-0.4)%	-0.7 (-2.2)%	
SCAG			-1.4 (-2.4)%	-0.6 (-0.8)%	0.5 (0.1)%
SANDAG				-0.1 (-0.1)%	0.0 (0.0)%

Consistent with the regional results, the magnitude of changes in interregional travel is generally greater in the land use scenario than the transit scenario, both in the case of negative changes (e.g. reductions in VMT) and of positive changes, as in corridor between SACOG and SJV. This confirms the very high relevance of land use organization in affecting travel behavior in a context, such as California, which for many decades has promoted forms of land use development that encourage the use of private cars for individual mobility. Similar to what observed for the regional analysis, significant differences are seen between the areas of MTC and SACOG (with higher land use impacts), compared to SJV and SCAG (with higher transit impacts).

Table 6-7: Change in Regional Interregional Flows (Land Use SCS vs. Control Scenarios)

Region	MTC	SACOG	SJV	SCAG	SANDAG
MTC	-7.6 (-9.3)%	-3.9 (-3.5)%	-3.0 (-4.6)%		
SACOG	-2.9 (-3.3)%	-0.5 (0.0)%	3.9 (2.2)%		
SJV	-4.3 (-4.9)%	1.9 (1.6)%	-0.4 (-0.2)%	-0.1 (-0.1)%	
SCAG			0.1(0.0)%	-0.6 (-0.3)%	0.9 (0.1)%
SANDAG				0.3 (-0.1)%	-0.3 (0.1)%

This project was developed using the California Statewide Travel Demand Model which, due to its large-scale statewide focus, allows for the simulation of regional policies using consistent modeling assumptions and methodologies across the entire state, while developing estimates on the impact of regional policies on interregional travel flows. Given the different scale of the model, it is not easy to directly compare the results from the application of the CSTDM modeling framework to the evaluation of these policy scenarios with the results from studies developed at the regional scale. For this reason, this study does not aim to substitute, but it rather complements, the results from MPO evaluation of policy scenarios of future development. Just for informative purposes, and to provide some terms of comparison with recently posted official results from the simulation of the proposed policies developed by local MPOS, Table 6-8 compares the VMT per Capita results obtained from the SCS model run with the results provided in the most recent RTP/SCS documents from regional MPOs.

Table 6-8: Comparison of VMT/Capita between Modeling Results and Estimations from the Four Major MPOs in California

Region	VMT (1000s)		VMT/Capita (Modeling Results)		VMT/Capita (from MPOs)	
	Control	SCS	Control	SCS	Control[1]	SCS[2]
MTC	162,349	151,906	18.2	17.0	21.2	19.6
SACOG	64,293	63,628	20.5	20.3	22.2	24.1
SANDAG	84,312	84,500	21.0	21.0	28.5	24.3
SCAG	446,834	442,547	20.2	20.0	26.1	23.5

[1] From older RTP documents;

[2] According to the most recent RTP/SCS documents.

The model results from this study tend to be rather homogenously below the most recent estimates for VMT/Capita from the four major MPO models. This might be due to a number of reasons, including different modeling assumptions in the estimation of modeling outcomes across MPOs and in comparison with the CSTDM model, and the potential underestimation of some components of local VMTs in the statewide model.[2] However, the comparison of the modeling outcomes with the MPO estimates identifies a similar trend in the distribution of VMT/Capita in the main regions of California. It should be also noted that a similar distribution of forecasted VMT/Capita by region has been recently reported also by the California ARB (cf Figures 3-4, 3-5, 3-6), although with generally lower estimates for VMT/Capita than in the MPO computations, and therefore closer to the modeling results from this study.

Mode share is another useful metric to compare, but due to either the lack of information on certain trips (often, only work trip share is reported) or lack of information for this statistic altogether, sufficient data for comparison was available for only two major MPOs. This highlights an interesting issue, as despite the establishment of some consistency in metric reporting across MPOs under the requirements of SB 375, still quite a large degree of variety exists in the way modeling outcomes are reported by different MPOs, and some other metrics are only reported by some MPOs. Table 6-9 summarizes the results for the only regions where sufficient data were available: the MTC and the SACOG regions. While the model results report slightly lower non-auto trip share than the objective/estimates from the latest RTP/SCS for MTC, the mode share for non-auto trips is higher in the SACOG estimates than in the model estimates.

Table 6-9: Comparison of Model and MPO Non-Auto Mode Share

Region	Model Non-Auto Share			MPO Non-Auto Share		
	Control	SCS	SCS - Control	Control	SCS	SCS - Control
MTC	13.50%	19.50%	6.00%	*(N/A)*	20.00%	*(N/A)*
SACOG	9.10%	9.10%	0.00%	11.65%	15.13%	3.48%

---

[2] Additional differences exist in the way each MPO reports their results. For example, several MPOs do not specify whether they include intrazonal VMT in their estimates. Also, the reference year for the "control" estimates was 2030 for SANDAG and 2040 for MTC.

7. Summary and Suggestions for Future Research

The Sustainable Community Strategies (SCSs) mandated by California SB 375 seek to reduce environmental externalities from transportation and improve the quality of life in metropolitan areas across the state. One of the pillars behind the adoption of the Sustainable Community Strategies is the understanding that new vehicle technology and the increased use of low carbon fuel can only partially contribute to the proposed reductions in GHG emissions from transportation. Therefore, there is a need for the coordination of land use changes and transportation policies, in order to achieve the environmental goals of AB 32. One of the major question that planners are called to answer is whether these new policies, and the way they will be implemented by local administrations, will actually be able to reduce the CO_2 emissions generated by transportation and increase the livability, health, and safety of California's communities over the next 20 years.

This study uses the California Statewide Travel Demand Model to evaluate the potential travel response to some land use changes and transportation policies contained in the smart growth-inspired SCSs developed by regional metropolitan planning organizations (MPOs). The research investigates the impact of population and employment distribution changes (including infill and transit oriented development) and increased transit services (including the extension of access and increased level of service) through the modeling simulation of a SCS-inspired scenario. The results from this model are compared to a control "business as usual" scenario. The control scenario mimics the land use and transportation investments planned for 2035 before the adoption of the recent SCS policy packages. The SCS scenario is built on information contained in the adopted (or draft) SCSs from local MPOs, where already available, or based on some land use and transportation changes that mirror similar policies for the remaining areas. By comparing the travel outcomes between the two scenarios, the study provides insight into the change in travel patterns that can be (at least partially) attributable to SB 375 and the Sustainable Community Strategies.

The use of the CSTDM framework in this study provides three main advantages, if compared to regional studies that evaluate the impact of the proposed policies using MPO models that operate at regional scales. First, it allows modeling the effects of the proposed policies using consistent modeling assumptions for the entire State of California, overcoming possible differences in the computation of modeling results. Second, it provides for a broader evaluation of policies by simulating both regional (short distance) and interregional components of travel. Third, it provides information on the marginal modifications introduced in transportation patterns by the adoption of the recent SCS plans, compared to the previous trends resulting from previous policy and investment plans. Thus, this study complements (and does not substitute) the use of regional models for the evaluation of these policies, and provides information for researchers and policy-makers on the overall impact of the proposed policies and possible ways to further increase their success.

According to this modeling study, the proposed policies can contribute to reduce short distance personal VMT in 2035, on average, 2.8% in the entire State, if compared to current trends that would be obtained if these policies had not been developed. Quite large variation in these results exists, however. Forecasted VMT reductions range between 0.6% in the San Diego

(SANDAG) region and 9.7% in the MTC region (San Francisco Bay Area). Increases in transit mode share are usually observed in each MPO with a published SCS. In general, higher increases in the percentage of population served by transit and in the urban density in transit corridors are associated with more environmentally-benign travel outcomes, as found in the densest areas of the State.

The synergy analysis conducted as part of this study compared the results of two partial land use and transit scenarios (which evaluate the impact of each group of policies in isolation) with the combined SCS scenario for 2035. Results indicate that the proposed land use policies generally have higher magnitude effects than the proposed transit investments, with specific results that vary across regions. In both regional and interregional travel, the combined SCS scenario is accredited of better (i.e. more environmentally benign) outcomes than the combined effects of the separate scenarios. This result shows a clear tendency for synergistic effects of the two groups of policies that were analyzed. It also confirms the appropriateness of the foundation of the SB 375 requirements, which specifically dictate for explicit coordination of land use policies and transportation investments. In fact, from the analysis of the modeling results, the combined SCS scenario resulted in significantly lower VMT in both short-distance regional VMT measures, and interregional VMT (and number of trips), compared to the additive changes from the two separate partial scenarios. These results encourage integrated policies that both shift land uses, while providing more sustainable forms of transportation.

The CSTDM model outcomes from this study are conservative when compared to results published in the RTP/SCS documents from local MPOs. Changes in VMT per capita estimates in 2035 (from the Control “business as usual” scenario to the SCS scenario) in the state’s four largest MPOs often deviate largely from the MPO estimates. This might be, however, partially due to differences in modeling assumptions across regions, differences in the estimates reported by MPO documents as well as to several smaller scale policy changes that could not be fully simulated with the statewide model.

Taken collectively, results from this study indicate that changes in land use and transit investment in published Sustainable Community Strategies will contribute to lower VMT and increase non-motorized travel in short distance passenger travel. Integrated transportation-land use plans indeed hold promise for sustainable travel in the future. However, several uncertainties are associated with the expected outcomes from these policies, and it is not entirely clear whether these policies will be actually able to achieve the proposed targets of reduction in transportation-related emissions. Moreover, many regions still need to develop their updated RTP/SCS plans, and therefore only speculations on the potential changes associated with scenarios that mimic similar planning policies adopted by other regions can be carried out, to date. Finally, the correct implementation of SCS requires strict cooperation and action alignment between local and regional governments. To date, it is still largely unknown to what extent many land use changes designed by regional MPOs will be actually implemented at the local level, also considering political, fiscal, and other constraints.

Acknowledgments

This project was funded by the University of California Transportation Center (UCTC), which receives funding from the U.S. Department of Transportation and the California Department of Transportation (Caltrans). The authors wish to thank David Ory at the Metropolitan Transportation Commission (MTC), Shengyi Gao, Gordon Garry and Bruce Griesenbeck at the Sacramento Area Council of Governments (SACOG), Sungbin Cho, Bayarmaa Aleksandr and Mike Ainsworth at the Southern California Association of Governments (SCAG), Daniel Flyte and Yang Wang at the San Diego Association of Governments (SANDAG), Julio Perucho at the Santa Barbara County Association of Governments (SBCAG), Brian Lasagna at the Butte County Association of Governments (BCAG), and Karen Fink at the Tahoe Metropolitan Planning Organization (TMPO). The CSTDM modelling program was funded by the California Department of Transportation (Caltrans). Additional funding for the development of this modelling framework and future scenarios was provided by the California High Speed Rail Authority, the Hewlett Foundation, the Surdna Foundation, and the Rockefeller Foundation. The authors wish to thank the many colleagues at the Urban Land Use and Transportation Center of the University of California, Davis, and at HBA Specto Inc. of Calgary, Alberta, Canada, for their valuable work during the development of the CSTDM framework on which this research was based.

Glossary

ABAG	Association of Bay Area Governments
BART	Bay Area Rapid Transit
BRT	Bus Rapid Transit
CALTRANS	California Department of Transportation
CARB	California Air Resources Board
CEQA	California Environmental Quality Act
DOT	Department of Transportation
GHG	Greenhouse Gas Emissions
HOV	High Occupancy Vehicle
LOS	Level of Service
MPO	Metropolitan Planning Organization
MTC	Metropolitan Transportation Commission
RTP	Regional Transportation Plan
SACOG	Sacramento Area Council of Governments
SANDAG	San Diego Association of Governments
SBCAG	Santa Barbara County Association of Governments
SCAG	Southern California Association of Governments
SCS	Sustainable Community Strategy
SOV	Single Occupancy Vehicle
TAZ	Traffic Analysis Zone
TOD	Transit Oriented Development
UC DAVIS	University of California at Davis
UCTC	University of California Transportation
ULTRANS	Urban Land Use and Transportation Center
(US) DOT	United States Department of Transportation
(US) EIA	United States Energy Information Administration
(US) EPA	United States Environmental Protection Agency
VMT	Vehicle Miles Traveled

References

Aditjandra, P. (2013) The Impact of Urban Development Patterns on Travel Behaviour: Lessons Learned from a British Metropolitan Region Using Macro-Analysis and Micro-Analysis in Addressing the Sustainability Agenda. *Research in Transportation Business & Management*

California Air Resource Board (2008) Climate Change Scoping Plan a framework for Change, December

California Air Resource Board (2013a) SACOG SCS Fact Sheet http://www.arb.ca.gov/cc/sb375/sacog_fact_sheet_for%20posting.pdf, accessed on December 30, 2013.

California Air Resource Board (2013b) SANDAG SCS Fact Sheet http://www.arb.ca.gov/cc/sb375/sandag_fact_sheet_for%20posting.pdf, accessed on December 30, 2013.

California Air Resource Board (2013c) SCAG SCS Fact Sheet http://www.arb.ca.gov/cc/sb375/scag_fact_sheet_for%20posting.pdf, accessed on December 30, 2013.

Bartholomew, K. (2005) "Integrating Land Use Issues into Transportation Planning: Scenario Planning—Summary Report," obtained from http://faculty.arch.utah.edu/bartholomew/SP_SummaryRpt_Web.pdf

Bartholomew, K. (2007) "Land Use-Transportation Scenario Planning: Promise & Reality." *Transportation,* 34(4), pp. 397–412.

Bechx, C., S. Broekx, B. Degraeuwe, B. Beusen, and L. I. Panis (2013) Limits to active transport substitution of short car trips, *Transportation Research Part D: Transport and Environment*, 22, pp. 10-13

Bhat, C.R., and J.Y. Guo (2007) A Comprehensive Analysis of Built Environment Characteristics on Household Residential Choice and Auto Ownership Levels, *Transportation Research Part B*, 41(5), pp. 506-526.

Boarnet, M., and R. Crane (2001) The influence of land use on travel behavior: specification and estimation strategies. *Transportation Research Part A: Policy and Practice* 35, pp.823-845

Butte County Association of Governments (2012) RTP, Accessed http://www.bcag.org/Planning/2012-MTP/Sustainable-Communities-Strategy/index.html on December, 1 2013

Cervero, R., and G.B. Arrington (2008) Vehicle Trip Reduction Impacts of Transit-Oriented Housing, *Journal of Public Transportation* 11(3)

Chatman, D. (2008) Deconstructing development density: quality, quantity and price effects on household non-work travel. *Transportation Research Part A: Policy and Practice* 42 (7), pp. 1008-1030.

Circella, G., J. D. Hunt, K. J. Stefan, A. T. Brownlee and M. McCoy (2011) Simplified Model of Local Transit Services, *90th TRB - Transportation Research Board Meeting*, Washington D.C., U.S.A.

Circella, G., J. D. Hunt, K. J. Stefan, A. T. Brownlee and M. McCoy (*forthcoming*) Simplified Model of Local Transit Services, *European Journal of Transport and Infrastructure Research.*

Ewing, R. and R. Cervero (2010) Travel and the Built Environment - A Meta-Analysis *Journal of the American Planning Association*, 76(3), pp. 265-294.

Ewing, R., R. Pendall, and D. Chen. (2003) "Measuring Sprawl and Its Transportation Impacts." *Transportation Research Record*, 1832, pp. 175–183.

Flybjerg, B., M.S. Holm, and S. Buhl (2002) Underestimating Costs in Public Works Projects: Error or Lie? *APA Journal* 68(3),pp. 279-295.

Handy, S. (2005) Smart Growth and the Transportation-Land Use Connection: What does the research tell us? *International Regional Science Review*, 28(2), pp. 146-167.

Handy, S., C. Cao, and P. Mokhtarian (2005) Correlation or causality between the built environment and travel behavior? Evidence from Northern California. *Transportation Research Part D: Transport and Environment* 10(6), pp. 427-444.

Heres-Del-Valle, D. and D. Niemeier (2011) CO2 emissions: Are land-use changes enough for California to reduce VMT? Specification of a two-part model with instrumental variables. *Transportation Research Part B* 45, pp. 150-161.

Khademi, E. and H. Timmermans (2011) Incorporating Traveler Response to Pricing Policies in Comprehensive Activity-Based Models of Transport Demand: Literature Review and Conceptualisation. *Procedia - Social and Behavioral Sciences* 20, pp. 594-603.

Kitamura, R., E. Eric, C. V Lula, T. K. Lawton, and P. E. Besnon. (1996) The sequenced activity mobility simulator (SAMS): an integrated approach to modeling transportation , land use and air quality. *Transportation*, 23, pp. 267–291.

Lemp, J. and K. Kockelman (2009) Anticipating Welfare Impacts via Travel Demand Forecasting Models: Comparison of Aggregate and Activity-Based Approaches for the Austin, Texas Region. *Transportation Research Record,* 2133, pp. 11-22.

Lund H., R. Willson, and R. Cervero (2006) A re-evaluation of travel behavior in California TODs. Journal of Architechture and Planning Research, 23(3), pp. 247–263.

Mees, P. (2009) *Transport for Suburbia: Beyond the Automobile Age.*

Metropolitan Transportation Commission (2013) Regional Transportation Plan, http://onebayarea.org/plan-bay-area/final-plan-bay-area.html, accessed on December 30, 2013.

Metropolitan Transportation Commission (2013b) Summary of Predicted Traveler Responses, Technical Supplementary Report from 2013 Regional Transportation Plan, http://onebayarea.org/plan-bay-area/final-plan-bay-area/final-supplementary-reports.html, accessed on December 30, 2013.

Millward, H., J. Spinney, and D. Scott (2013) Active-transport walking behavior: destinations, durations, distances, Journal of Transport Geography, 28, pp. 101-110.

Mindali, O., A. Raveh, and I. Salomon (2004) Urban density and energy consumption: a new look at old statistics. *Transportation Research Part A: Policy and Practice* 38(2), pp. 143-162.

Mitchell, R. and C. Rapkin (1954) “Urban Traffic - A Function of Land Use.” *National Municipal Review* 43(11), pp. 608-609.

Moore, A., S. Staley, and R. W. Poole Jr. (2010) The role of VMT reduction in meeting climate change policy goals, *Transportation Research Part A: Policy and Practice*, 44(8), pp. 565-574.

National Research Council (2006) *NCHRP Synthesis 358: Statewide Travel Forecasting Models*. Washington, DC: The National Academies Press

Newman, P. and J. Kenworthy (1989) Gasoline consumption and cities: A comparison of U.S. cities with a global survey. *Journal of American Planning Association* 55(1), pp. 24–37.

Parker, T., M. McKeever, G. Arrington, and J. Smith-Heimer (2002) Statewide Transit-Oriented Development Study Factors for Success in California, http://transitorienteddevelopment.dot.ca.gov/miscellaneous/StatewideTOD.htm, accessed on December 30, 2013.

Pendyala, R., T. Yamamoto, and R. Kitamura (2002) On the formulation of time-space prisms to model constraints on personal activity-travel engagement. *Transportation*, 29, pg. 73–94.

Recker, W. W., and a. Parimi (1999) Development of a microscopic activity-based framework for analyzing the potential impacts of transportation control measures on vehicle emissions. *Transportation Research Part D: Transport and Environment*, 4(6), pp. 357–378.

Rodier, C. J., R. Johnson, and J. Abraham (2002) Heuristic policy analysis of regional land use, transit, and travel pricing scenarios using two urban models. *Transportation Research Part D: Transport and Environment* **7**(4), pp. 243-254.

Rodier, C. (2009) “A Review of the International Modeling Literature: Transit, Land Use, and Auto Pricing Strategies to Reduce Vehicle Miles Traveled and Greenhouse Gas Emissions” *Transportation Research Record*, 2132, pp 1-12.

Rose, E. (2011) Leveraging a New Law: Reducing greenhouse gas emissions under Senate Bill 375. Berkeley: Center for Resource Efficient Communities, College of Environmental Design at the University of California, Berkeley.

Sacramento Council of Governments (2012) Metropolitan Transportation Plan, http://www.sacog.org/2035/mtpscs/, accessed on December 30, 2013.

San Diego County Associate of Governments (2012) Regional Transportation Plan, http://www.sandag.org/index.asp?projectid=349&fuseaction=projects.detail, accessed on December 30, 2013.

Santa Barbara Association of Governments (2013) Regional Transportation Plan, http://www.sbcag.org/planning/2040RTP/Documents.html, accessed on December 30, 2013.

Shiftan, Y. and M. Ben-Akiva (2011). A practical policy-sensitive, activity-based, travel-demand model. *The Annals of Regional Science*, 47, pp. 517-541.

Shiftan, Y. and J. Suhrbier (2002) The Analysis of Travel and Emission Impacts of Travel Demand Management Strategies Using Activity-Based Models. *Transportation*, 29(2), pp. 145-168.

Stopher, P (2002) Deficiencies of Travel-Forecasting Methods Relative to Mobile Emissions. *Journal of Transportation Engineering*, 119(5), pp 723–741.

Southern California Association of Governments (2012) Regional Transportation Plan, http://rtpscs.scag.ca.gov/Pages/2012-2035-RTP-SCS.aspx, accessed on December 30, 2013.

Tahoe Metropolitan Planning Organization (2012) Regional Transportation Plan, http://tahoempo.org/Mobility2035/, accessed on December 30, 2013.

Tschangho, J.K (1983) A combined land use-transportation model when zonal travel demand is endogenously determined, *Transportation Research Part B: Methodological*, 17(6), pp. 449-462.

United States Department of Health and Human Services, DHHS (2008) Physical Activity Guidelines Advisory Committee Report, Physical Activity Guidelines Advisory Committee. Office of Public Health and Science, U.S. Department of Health and Human Services. Washington, DC.

United States Department of Transportation (2008) National Household Travel Survey, Federal Highway Administration, Office of Highway Policy Information

United States Department of Transportation (2009). Partnership Sets Forth Six 'Livability Principles' to Coordinate Policy, Press Release. US Department of Transportation, Office of Public Affairs, DOT 80-0916 June 2009.

United States Energy Information Administration (2007) *Annual Energy Outlook 2007*. Washington, D.C.: U.S. Department of Energy.

United States Environmental Protection Agency (2000) Projecting Land-Use Change, A summary of models for assessing the effects of community growth and change on land-use patterns. PA/600/R-00/098. U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH.

Urban Land Use and Transportation Center and HBA Specto. (2011) CSTDM09-Model Development: Model Overview. Institute of Transportation Studies, University of California, Davis. Available at: http://ultrans.its.ucdavis.edu/doc/cstdm-documentation, accessed on December 30, 2013.

Urban Land Use and Transportation Center and HBA Specto (2011) *CSTDM09-Model Development: Short Distance Personal Travel Model*. Institute of Transportation Studies, University of California, Davis. Available at: http://ultrans.its.ucdavis.edu/doc/cstdm-documentation, accessed on December 30, 2013.

Urban Land Use and Transportation Center and HBA Specto (2011) *CSTDM09-Model Development: Long Distance Personal Travel Model*. Institute of Transportation Studies, University of California, Davis. Available at: http://ultrans.its.ucdavis.edu/doc/cstdm-documentation, accessed on December 30, 2013.

Urban Land Use and Transportation Center and HBA Specto (2011) *CSTDM09-Model Development: Short Distance Commercial Vehicle*. Institute of Transportation Studies, University of California, Davis. Available at: http://ultrans.its.ucdavis.edu/doc/cstdm-documentation, accessed on December 30, 2013.

Urban Land Use and Transportation Center and HBA Specto (2011) *CSTDM09-Model Development: Long Distance Commercial Vehicle Model*. Institute of Transportation Studies, University of California, Davis. Available at: http://ultrans.its.ucdavis.edu/doc/cstdm-documentation, accessed on December 30, 2013.

Urban Land Use and Transportation Center and HBA Specto (2011) *CSTDM09-Model Development: External Travel Model*. Institute of Transportation Studies, University of California, Davis. Available at: http://ultrans.its.ucdavis.edu/doc/cstdm-documentation, accessed on December 30, 2013.

Walmsley, D.A, and M.W. Pickett (1992) The Costs and Patronage of Rapid Transit Systems Compared with Forecasts, *Transportation Research Labaratory, Department of Transportation Crowthorne, Berkshire,* Research Report 352.

Walters, J., R. Ewing, and E. Allen. (2000) “Adjusting Computer Modeling Tools to Capture Effects of Smart Growth.” *Transportation Research Record*, 1722, pp. 17–26.

Weiner, Edward *Urban Transportation Planning in the United States: An Historical Overview* www.cts.umn.edu/trg/publications/pdfreport/TRGrpt2.pdf, accessed on December 30, 2013.

Zhou J. (2012) Sustainable transportation in the US: A review of proposals, policies, and programs since 2000, *Frontiers of Architectural Research*, 1(2), pp. 150-165.