# Description of Methodology for ARB Staff Review of Greenhouse Gas Reductions from Sustainable Communities Strategies (SCS) Pursuant to SB 375

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## Executive Summary

The Sustainable Communities and Climate Protection Act of 2008 (Sustainable Communities Act or SB 375) supports California's climate goals by linking integrated land use and transportation planning, with reductions in greenhouse gas (GHG) emissions. The addition of Sustainable Communities Strategies (SCS) to regional transportation plans makes that connection and provides the opportunity for better community design and more efficient use of resources. The first round of SCS development is underway reflecting the greenhouse gas reduction targets adopted by the Air Resources Board (ARB or Board) in 2010. The purpose of this document is to inform the public about the methodology ARB staff will use to evaluate GHG reductions from an SCS, consistent with ARB's role in SB 375.

Now that the Board has adopted the GHG targets for each region, ARB's next task is to determine whether an adopted SCS, if implemented, would meet the assigned target. ARB staff will complete a technical evaluation using this general methodology and recommend to the Board whether or not the target can be expected to be met if the SCS is implemented. While land use decisions and transportation planning are local and regional responsibilities, ARB does have the role of determining whether an SCS, as part of the regional transportation plan, would achieve its emission reduction target.

ARB staff's review will focus on the technical aspects of the regional modeling and supporting analyses that underlie the GHG quantification. To evaluate the reductions in VMT-related emissions expected from the SCS, modeling results and data inputs will be reviewed. The methodology is intended to provide the framework for a transparent evaluation of an SCS and its associated reductions in GHG emissions. Staff will adapt this basic approach to review of the SCS for each Metropolitan Planning Organization (MPO), considering model complexity, resources, and unique characteristics of the region and the models used.

It is important to note that the overall approach will evolve as more SCSs are reviewed over time, MPOs gain experience with the application of travel demand models to SCS development, and the technical tools continue to improve. As recognized in ARB's target setting process, MPOs are making improvements to their models with support by ARB and others. Since travel models are region-specific and may differ in the ability to accurately reflect the benefits of GHG reduction strategies, MPOs may need to rely on additional analyses to supplement model results. ARB's methodology takes this into account.

The first round of SCS development under SB 375 is just the beginning of a long-term effort to include consideration of GHG reductions in the land use and transportation planning process. ARB will periodically revisit the targets, MPOs will update regional transportation plans and the SCS, and modeling capabilities will continue to improve. ARB's methodology for reviewing an SCS will also be revised over time as new information and technical tools become available.

# I. Introduction

This document describes ARB staff's technical methodology for evaluating the reductions in GHG emissions attributable to an SCS to determine whether the SCS, if implemented, would meet the targets for passenger vehicles set by ARB. The GHG emission reduction targets for this first round of SCS development were adopted by ARB in 2010. Since the SCS is developed as a component of the Regional Transportation Plan (RTP), transportation modeling systems play an important role in quantifying the emissions benefit of an SCS.

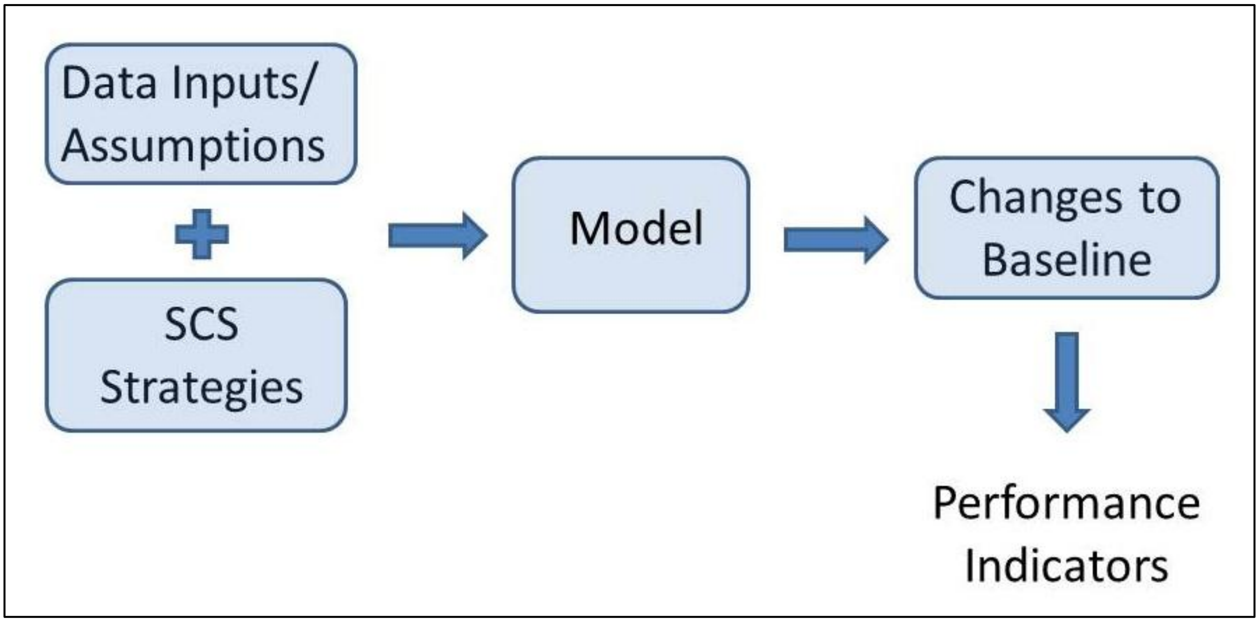
This methodology focuses on a review of how well the region's travel demand modeling and related analyses provide for the quantification of GHG emission reductions associated with the SCS. Travel demand models, as well as off-model tools, are an essential, inextricable part of the regional transportation planning process. Modeling tools are used in transportation conformity determinations to ensure regions are on track to meet federal air quality requirements. They are also used by MPOs for assessing the air quality impacts of RTPs for purposes of the State's environmental review process (e.g., Environmental Impact Reports).

The flow chart in Figure 1 represents the basic components of the modeling system that are the focus of ARB's evaluation relative to GHG reductions. Although the complexity and degree of specialization may vary among the regional models, the basic components are common across regions. As illustrated in the diagram, the process begins with the MPO converting relevant data sets, such as base year population, number and size of households, and land uses into modeling inputs. For example, the average number of people per household is converted to an average number of vehicle trips per day per household.

The MPO also inputs planning assumptions into the model about future year land use, housing, and transportation policies that affect GHG emissions from passenger vehicles. Through a set of algorithms, the model uses these inputs to project future conditions based on changes in land use, transportation systems, and travel activity. Model outputs include, but are not limited to vehicle miles traveled (VMT), vehicle trips, and average speed.

Model outputs are used to develop performance indicators, which are metrics to assess the performance of the RTP/SCS in reducing future year GHG emissions. For example, performance indicators can be used to indicate whether the SCS evaluated in the model reduces average commute trips in future years when compared with a baseline year.

**Figure 1: Basic Travel Model System**



## II. **Overview of Approach**

One of ARB's responsibilities under the Sustainable Communities Act is to determine whether an SCS, if implemented, will achieve the GHG emission reduction targets based on MPO planning assumptions, modeling results, and available resources. ARB's approach focuses on evaluating the four key components of an MPO's travel demand modeling system: modeling tools, model data inputs and assumptions, sensitivity analyses, and performance indicators. Each is critical to provide an understanding of model operation and performance.

The following are some key questions:

- Did the MPO use adequate modeling and analysis tools to develop the SCS?

- Does the model use the regional land use and transportation systems to reflect current (or base-year) conditions? How do the projections used in the model account for expected regional demographic and economic changes?

- Are the projected GHG reductions consistent with the timing of project implementation, expected resources, and the types of projects modeled for the RTP/SCS?

- What is the relative contribution of specific SCS strategies or groups of strategies to the overall GHG reduction from passenger vehicles?

To address these key questions, ARB will request information from the MPOs related to the four components of the modeling system, including but not limited to:

- Model documentation, model validation reports, peer review reports, and model sensitivity tests.

- Data, assumptions, and calculations the MPO used to develop the model inputs for the SCS.

- Results of select model runs to determine the sensitivity to particular strategies in the SCS in achieving GHG reductions. The number and type of sensitivity tests will be determined by ARB on a case-by-case basis taking into consideration the potential significance of particular SCS elements in a region.

- Information on regional performance indicators to determine whether, for the region as a whole, GHG reductions are consistent with modeled regional changes in per capita VMT, land use patterns, and vehicle activity patterns.

Subsequent sections of this document discuss in detail how ARB will apply this information. Additionally, Appendix A provides examples of related questions and data.

The general procedures presented in this document will be adapted for each MPO, considering model complexity, resources, and unique characteristics of the region and its SCS.  The overall approach will evolve as more SCSs are reviewed over time, and as MPOs gain experience and improve their technical tools.  All information used by ARB will be made publicly available to ensure that the evaluation process is transparent.

## III. Travel Demand Models

Each of California's MPOs uses and maintains a travel demand model for the development and evaluation of its RTP. These models are computer tools used to forecast future travel based on simulations of complex interactions among demographics, land use development patterns, transportation infrastructure, and other related factors. Models should be able to reflect both existing conditions, and the expected traveler response to a region's infrastructure investments, policies, strategies, and future traffic patterns. These tools are used by MPOs for a number of purposes, including compliance with State and federal air quality and transportation planning requirements, and analyses required by the California Environmental Quality Act.

Early in the implementation of the Sustainable Communities Act, travel demand models were recognized as crucial elements in demonstrating whether MPOs meet the GHG emission reduction targets. These models play an integral role in transportation planning by providing the technical foundation and data upon which the RTP, and therefore the SCS, is built. ARB staff will evaluate each MPO's travel model to assess how well it demonstrates the relationship between land use and transportation changes and reductions in GHG emissions. In evaluating whether or not an MPO's model is reasonably sensitive for this purpose, ARB staff will review the MPO's technical documentation for the model and off-model tools, as well as its model validation, adherence to modeling guidelines, and any independent reviews of the models such as review by the Federal Highway Administration. In addition, ARB staff will review key modeling variables in the model documents (e.g., calibration, validation, sensitivity analysis and peer-review results), and compare them to independent data sources such as Institute of Transportation Engineers (ITE) manual, National Household Travel Survey (NHTS), Caltrans traffic count and flow information, and others.

The travel demand models exhibit different levels of sophistication in terms of model capabilities, and there are ongoing efforts to improve the way models address the following types of information:

- Trip chaining – linking together a series of daily trips made by an individual
- Induced demand – in which roadway congestion relief projects lead to additional congestion over time
- Pricing – tolls, high occupancy toll (HOT) lanes, parking, and congestion
- Improvements in traffic operations (transportation system management – TSM)
- Non-motorized transport
- Transportation demand management (TDM) strategies
- Land use policies

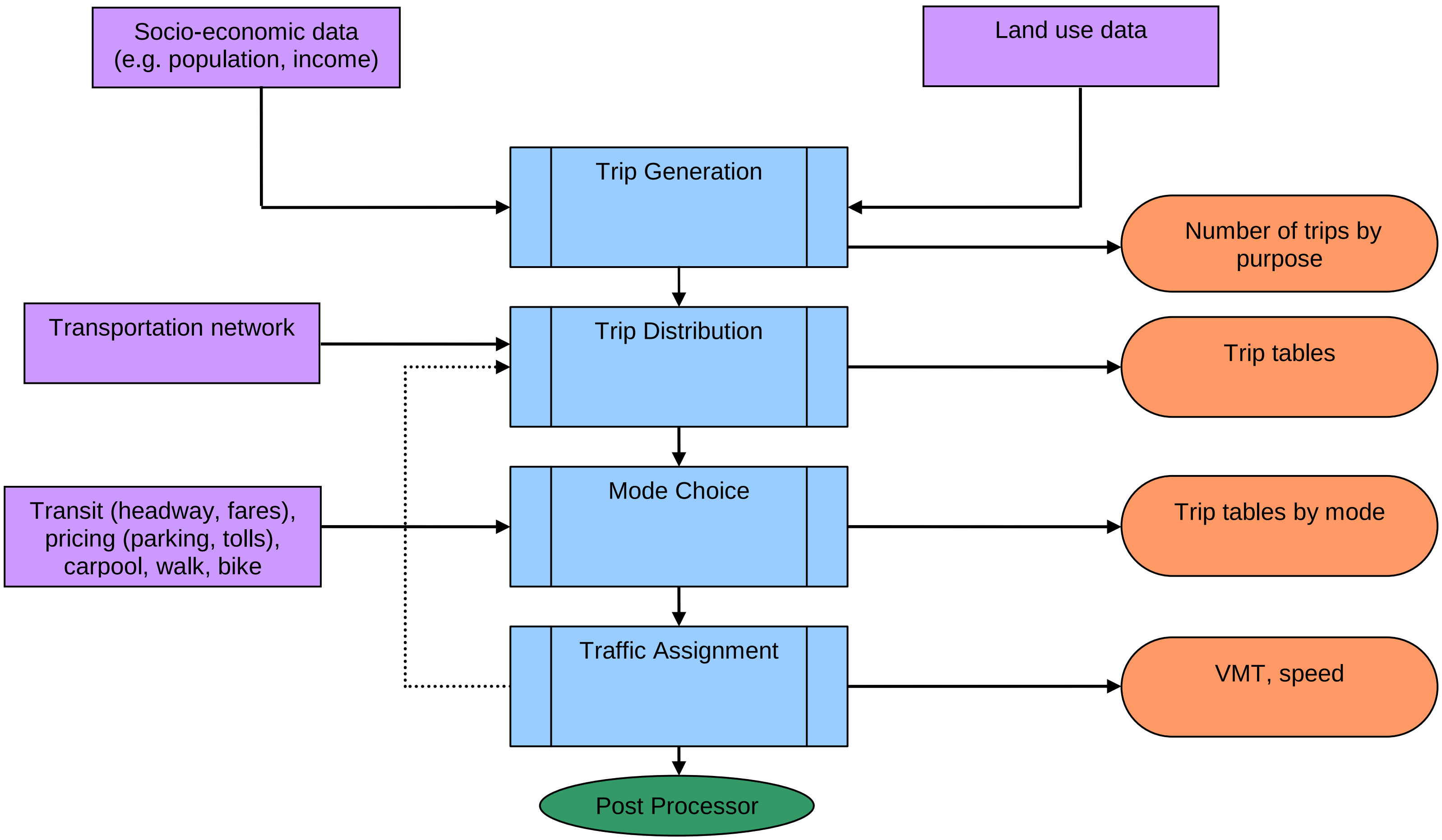
Since current travel demand models may not be sensitive to all the factors that may be useful in calculating GHG reductions, MPOs are encouraged to supplement modeling results with other analyses. Using sketch-planning tools or spreadsheet analyses in conjunction with conventional travel demand models can provide a more complete picture. Some MPOs are enhancing their existing travel demand models by developing new components such as improved mode choice models, and improved pricing components of the model.

### Description of a Four-Step Travel Demand Model

ARB will examine which travel models were used, how they were used for SCS application, and whether and how the MPO added model components or used off-model tools to capture the impacts of SCS policies on GHG emissions.

Most of the MPOs currently use a four-step model. The major elements of this type of model are trip generation, trip distribution, mode choice, and traffic assignment, as shown in Figure 2.

**Figure 2. Typical Four Step Travel Demand Model**



Step 1: Trip Generation

Trip generation is the first step in the four-step process. The purpose of this step is to estimate the number of person or vehicle trips in the study area for activities such as work, school, shopping, and recreation. MPOs generally use between three and nine activity categories in their models. The trip generation step of the model has two sub-models, namely trip production and trip attraction. Trips can be modeled at the zonal, household, or personal level. Most MPOs model trip production at the household level and trip attraction at the zonal level using socioeconomic data. As part of the evaluation of the trip generation step, ARB staff will identify key model variables (e.g., number of trips produced per household by purpose) and compare them to independent data sources.

Step 2: Trip Distribution

Trip distribution links the trip production and attraction at the transportation analysis zone level. In order to estimate the number of trips between zones, most MPOs use the gravity model, which relies upon land use patterns and travel impedance between zones. Some MPOs use destination choice models to distribute the trips. As the name indicates, these models use destination choice variables like employment and categories of land use (e.g., office space, shopping area), as well as traveler characteristics, such as income and vehicle ownership. ARB staff will evaluate such variables as average trip length by purpose in terms of both time and distance, and travel impedances between zones.

Step 3: Mode Choice

Mode choice is the third step in the four-step process. In this step, the mode choice of zone-to-zone trips is allocated based on available modes, trip purposes, and socio-economic characteristics. A few large MPOs include non-motorized modes as part of available modes. In this step of a travel demand model, 24-hour origin/destination matrices are converted to three to five time period matrices. Most MPOs use logit models to estimate the mode choice. Some MPOs use a time-of-day adjustment step after the mode choice step to allow the distinction between peak and off-peak periods and to help capture the direction of the traffic flow and the time period of congestion. In California, most MPOs use mode choice components of their four-step travel demand models, except for a few small MPOs. ARB staff's evaluation will include such modeling variables as mode share and average vehicle occupancy by trip purpose, and percentage of trips by time period in the region.

Step 4: Traffic Assignment

The last step in the four-step process is a traffic assignment that estimates the traffic volume and travel time in each link of the network for the specified time period. This is done by following the user equilibrium principle that balances route choice by considering a given trip's frequency, destination, mode choice, and time of day. In this step, all vehicles, including transit buses and freight trucks, are aggregated using a passenger car equivalent factor. Some MPOs may use more sophisticated equilibrium methods to more accurately capture the effect of congestion.

ARB staff will evaluate modeling variables such as the estimated traffic volume and speed by facility type in the region, and compare them to the observed traffic counts in the region using Performance Measurement System (PeMS) or other data sources.

Feedback Mechanisms to Estimate Traffic Flow

Many travel demand models include feedback mechanisms to estimate realistic traffic flow. Feedback is used to adjust the link volume and travel time based on the output from the previous iteration until model discrepancies are resolved. This is known as convergence. The inclusion of a feedback mechanism and the number of iterations vary from one MPO to another. ARB staff will review how well the feedback mechanism achieves convergence levels that are consistent with acceptable modeling practice.

**Model Technical Documentation**

ARB staff will examine the MPO's modeling documentation in order to assess whether an MPO's model reflects both the existing conditions and the likely traveler response to the SCS components. Specifically, staff will review the following:

The Model Validation, Calibration and Peer Review Processes

ARB will evaluate whether the MPO used models for the RTP and SCS process that are validated and calibrated, and have undergone a peer review. Model validation and calibration ensure that the model represents current or base year conditions, which are then reflected in travel forecasts. Calibration is conducted in each step of the travel demand model as the base year and model parameters are adjusted to match observed data. For future years, these parameters will be assumed constant.

The main purpose of model validation is to ensure that the model is capable of predicting future travel activity. This could involve a simple trend analysis or a sophisticated statistical analysis. The guidelines provided by the Federal Highway Administration (FHWA)[i] indicate that every component of the model should be validated, as well as the entire model system. Reasonableness checks are also performed for input data, model logic, and comparison of model results to results from independent data sources. These checks are conducted at both the disaggregate and aggregate levels. At the disaggregate level, the check evaluates the model parameters and coefficients and compares the predicted and observed behavior at the individual level. At the aggregate level, it focuses on the repeatability of the travel patterns at the regional level. Sensitivity tests are used to evaluate the elasticities of various policies to ensure that the output of the model is sensitive to variations in the input data. (An elasticity is the ratio of the percent change in a parameter divided by the percent change in another parameter.) Sensitivity analyses are discussed in more detail later in this document.

The peer review process occurs once the model is calibrated and validated. A panel of experts, typically from academia, government agencies, outside consultants, and other organizations familiar with the travel demand model and without a conflict of interest, evaluate the various components of the model. They also evaluate the data sources and underlying assumptions used at each step. The panel typically describes the strengths and weaknesses of the model, and provides short-term and long-term recommendations for improvement. The most common peer review process that any travel demand model goes through is the Travel Model Improvement Program (TMIP), which is funded by the FHWA.

Documentation of Off-Model Tools or Methods Used

There are several ways to improve the sensitivity of travel models to an SCS. Modeling can be enhanced through comprehensive updates that often involve significant data collection efforts, which can be costly and time-consuming. In lieu of or in conjunction with model updates, modelers often use off-model tools to adjust model outputs, such as vehicle trips or vehicle miles travelled, to account for the impacts of SCS components on vehicle use.

There are two types of commonly used off-model tools, sometimes referred to as spreadsheet tools and sketch planning tools. Spreadsheet tools apply the appropriate elasticities to the four-step model outputs to account for the impact of various policies. An example of a spreadsheet tool would be a “4D post-processor.” Sketch planning tools use similar elasticities combined with geographic information system (GIS) layers to pictorially display different land use and transportation system scenarios while calculating the resulting travel benefits. Examples of sketch-planning tools are IPLACE3S and INDEX. Such tools should ideally be calibrated to local conditions. To avoid double counting travel benefits, they also should only account for the elasticities not already incorporated into the travel demand model, to avoid double counting travel benefits. Modelers may use generic elasticities from national studies or borrow values from other regions, but these sources reduce accuracy of the results.

ARB will document whether each MPO employs the most appropriate tools to ensure its model is sufficiently sensitive to account for the impacts of its SCS on GHG emissions. ARB staff will also evaluate the off-model tools used by MPOs by comparing the elasticities in the model with those in the existing literature. Staff will also check the minimum and maximum bounds in the range of reasonable elasticities for different strategies. This evaluation will be discussed in the Sensitivity Analysis section.

Comparison of MPO Modeling Practice to “State-of-the-Practice”

Modeling practices for California MPOs are consistent with common modeling practices for similarly sized MPOs across the nation. Most MPOs employ some version of the four-step process outlined above, while only the largest engage in more sophisticated techniques like land use forecasting. For more information on common modeling practices, see Appendix B.

MPOs and other transportation agencies nationwide use several methods to develop travel models that are state-of-the-practice. The FHWA, within the U.S. Department of Transportation, must certify MPOs every three years. This certification process, which includes noticed, public workshops, includes an assessment of modeling practices used by the MPO in light of the requirements in federal regulation (23 Code of Federal Regulations, Part 450).

Additionally, most transportation agencies have standing technical or modeling advisory committees. For example, the Southern California Association of Governments convenes its Modeling Task Force bi-monthly to publicize and receive comment on a number of fundamental model assumptions during model development. The California Department of Transportation (Caltrans) sponsors the California Inter-Agency Modeling Forum at which MPO modeling practitioners present papers on current modeling practice. The larger MPOs also frequently publish papers for national organizations, such as the Transportation Research Board (TRB) and the National Cooperative Highway Research Project (NCHRP). These national forums provide a yardstick against which any MPO can assess the state of its modeling program. MPOs typically publish their model documentation on their websites for transparency and public access.

### EMFAC

The EMission FACtors (EMFAC) model is a California specific computer model that calculates daily emissions of air pollutants from all on-road motor vehicles including passenger cars, trucks, and buses for calendar years 1970 to 2040. The model, developed by ARB, estimates emissions using vehicle activity provided by regional planning organizations and emission rates developed from testing of in-use vehicles. In addition to statewide emissions, the model can also estimate emissions at the county, air district, and air basin levels. The current EMFAC2007 model estimates exhaust and evaporative hydrocarbons, carbon monoxide, oxides of nitrogen, particulate matter, oxides of sulfur, methane, and carbon dioxide ($CO_2$) emissions. EMFAC2007 can be downloaded from the ARB website at (http://www.arb.ca.gov/msei/msei.htm#background).

ARB maintains and periodically updates the EMFAC model and it has been peer reviewed and approved by U.S. EPA. EMFAC undergoes an extensive validation process, which includes comparing the model outputs with those from independent data sources, reconciliation of fuel consumption estimates with fuel sales data, and comparing modeled to ambient emission ratios.

ARB staff is currently updating the EMFAC2007 model and plans to release the next version of EMFAC in 2011. The next version will provide updated fleet mix and technology penetration for calendar years 1990 to 2035, and will reflect updated vehicle activity provided by planning organizations.

### EMFAC Post-Processor

ARB staff developed an EMFAC Post-Processor tool for MPOs to estimate the GHG emissions associated with their SCS while also considering the emission reduction benefits of California's vehicle and fuel standards. In 2007, ARB adopted the Pavley clean-car standards to reduce GHG emissions from passenger vehicles. In 2009, ARB adopted a Low Carbon Fuel Standard (LCFS) to reduce the carbon intensity of vehicle fuel. The Sustainable Communities Act further encourages a reduction of GHG emissions from passenger vehicle travel.

ARB staff expects that the MPOs will use this tool appropriately to estimate how the three strategies work together to reduce emissions. MPOs will input information on vehicle use (e.g., miles driven and speeds) from their travel demand models into the applicable ARB vehicle emissions model (currently EMFAC 2007). The EMFAC output will feed into the EMFAC Post-Processor tool to estimate future GHG emissions with the Pavley I and LCFS benefits; ARB staff used the same Post-Processor tool during the target setting process. ARB staff will review the MPO's use of this Post-Processor tool to ensure it is applied appropriately. The EMFAC post-processor will be updated as new motor vehicle emission standards go into place.

# IV. Model Inputs

The ability of a model to reliably reflect future travel activity is fundamentally tied to the quality of the model inputs. In order to review the technical soundness of the MPOs' modeling results, ARB staff will check the input data sets and assumptions to confirm they were appropriately used for the specific model, and that they represent current and reliable data. This review will consist of examining the underlying data source or sources, assumptions used to modify the data, and the forecasts used to calculate data in future years.

### Evaluation

ARB staff will request that each MPO provide the data, assumptions, and calculations it uses to develop the transportation model inputs for its SCS. Staff will evaluate these inputs using publicly available, authoritative sources of information (e.g., the Institute of Transportation Engineers, Caltrans, and the Highway Performance Monitoring System) to establish that the data, assumptions, and calculations are appropriate for SCS modeling, including whether unique differences resulting from local conditions, policies, or approach are substantiated. ARB staff will examine the data, assumptions and calculations used by each MPO as described below.

<u>Data and Assumptions</u>

Data are fundamental facts about people, places and things. A stretch of highway is a certain length, the average person is a given age, and urban areas encompass a defined space. Data can be directly observable, commonly through surveys, or developed by a recognized authority (e.g., the U.S. Census Bureau). The MPO relies on both these types of data when building its RTP/SCS.

In examining an MPO's data, key considerations include:

- The process for data collection, if the MPO gathered its own data;
- The primary source of the data and how it was validated; and
- Whether the data is comprehensive, touching on all the necessary attributes of population, employment and other key factors.

Data inputs must include some assumptions, typically based on expert judgment and available empirical evidence. MPOs use assumptions to fill in information gaps or interpret trends over a long planning horizon. By necessity, surveys to collect data typically sample a small but representative fraction of a population. Assumptions are then made about how the survey findings apply to the overall population. In examining an MPO's data, ARB staff will review key assumptions for reasonableness and consistency with empirical evidence and assumptions used by recognized organizations that generate similar information.

ARB will ask the MPOs to provide information for a set of fundamental model inputs, examples of which are shown in Table 1. Note that this list is shown for illustrative purposes only and ARB may request different information from MPOs. For instance, a region may not have toll roads or it may choose not to include HOT lanes in its RTP.

**Table 1: Examples of Fundamental Model Inputs**

| Category | Fundamental Model Input | Example of Outside Source for Model Input |
|---|---|---|
| Socio Economic | Population by age, income, household and auto ownership | 2010 CENSUS for population, household and household economic data<br>California Department of Finance demographic data |
| | Migration rate | |
| | Military population projection | |
| | Household, by household size and auto ownership | |
| | Workers by household size | |
| | Household vacancy rates | |
| | Employment by industrial classification | |
| | Unemployment rates | |
| Land Use | Regional Comprehensive Plan assumptions | General Plans |
| Highway Facilities | Highway capacity | Caltrans statewide economic database<br>http://www.dot.ca.gov/hq/tpp/offices/ote/socio_economic.html |
| | Highway network | |
| | Lane miles by facility | |
| | Facility free flow speed | |
| | High occupancy vehicle (HOV) lane miles | |
| | HOT lane miles | |
| Transit Facilities | Transit route network | Transit operators<br>Local agencies |
| | Transit speed | |
| | Transit route frequency | |
| Transportation Costs | Gasoline prices | CEC IEPR<br>Local surveys<br>Toll and transit operators |
| | Vehicle operating costs | |
| | Toll prices | |
| | Parking prices | |
| | Transit fares | |
| Travel Behavior | Trip generation rates | California Statewide Household Travel Survey for travel behavior<br>http://www.dot.ca.gov/hq/tsip/tab/travelsurvey.html |
| | Trip time distribution | |
| | Trip distance distribution | |

## Forecasts

Models are used to project data into the future and often rely on forecasted data to accomplish this task. The forecast is based on calculations, much like scaled down versions of the models described earlier in this document, which take the base year data and assumptions and project it to arrive at a future value. ARB will review the calculations to determine if they are reasonable, comparing them to those from independent data sources.

## V. Sensitivity Analysis

Sensitivity analyses examine the effect that specific changes within a model have on model outputs. It involves systematically changing one model input variable at a time (e.g., increased transit frequency, road pricing, land uses) to see how sensitive the model outputs, such as VMT, are to changes in the variable. ARB staff will use sensitivity analyses provided by the MPO to understand a model's capacity to effectively capture the GHG emission impacts of the SCS on key model outputs, such as VMT, trips, and ultimately GHG emissions. Where the model itself is not sufficiently sensitive, and the MPO has used supplemental off-model tools to estimate changes in model inputs affecting GHG emissions, ARB will also review these analyses along with modeling results. The analyses are expected to identify the magnitude of change in VMT, trips, and GHG emissions attributable to an SCS implemented at the regional level.

The FHWA's Travel Model Validation and Reasonableness Checking Manual emphasizes the importance of sensitivity tests to evaluating model performance:

> *"Sensitivity testing is not designed to tell whether the transportation models are correct, but, rather, provides information how the models behave for strategies. A well-structured sensitivity testing provides the opportunity to focus on the big picture of determining the overall reasonableness of the model in preparation for producing forecasts for specific studies."* [ii]

The California Transportation Commission (CTC) also recommends that experimental sensitivity tests be run to determine the corresponding changes in model output variables, and that the results be documented [iii]. Minimally, the outputs would be total VMT, light-duty vehicle total VMT, per capita light-duty vehicle total GHG emissions, and per capita total person trips and person trips by mode (i.e., automobile, transit, bike and walk). Documentation describing sensitivity test runs should identify a range of reasonable sensitivity based on empirical literature, and account for where in this range the travel demand model sensitivity falls.

In 2009, the MPOs did a qualitative self-assessment of the sensitivity of their models to a consistent set of almost 30 variables.[iv] These variables included transit fares, highway capacity, density, mix of use, pedestrian environment, and transit proximity. ARB staff's analysis will build upon the MPOs' assessment to develop a more quantitative understanding of each model's sensitivity to changes in key model inputs.

### Evaluation

In performing its review, ARB staff will determine the most relevant variables or groups of variables to provide information on the resulting elasticities, and request that each MPO conduct sensitivity analyses. Depending on the SCS and the capabilities of the MPO model, ARB staff may request MPO-specific sensitivity tests of either individual strategies or groups of strategies. Staff will then review the model sensitivity results, and compare them with available empirical literature or other pertinent information to determine if the MPO's elasticities generally fall within a reasonable range. If a range of observed variation is not available in the empirical literature, or no consensus exists as to the acceptable range of observed variation, staff will base its review on the best available information on travel behavior. Where the values provided by the MPO diverge greatly from the observed range of values, or where the relationships between model results and available literature are not easily explained, the MPO will be asked to provide further explanation for the variations.

The following is a list of core policy variables and factors associated with key land use and transportation-related components associated with GHG reductions. These variables and factors are consistent with those qualitatively assessed in the MPOs' model sensitivity analysis during the target setting process. While ARB staff believes this list includes the most important variables for analysis, staff realizes it may not be appropriate for an MPO to do a sensitivity test on each one, given the MPO's unique SCS, complexity, and resources.

Land Uses

a. Modify distribution of households, population, jobs or other variables
b. Rebalance the mix of land uses
c. Increase the level of density
d. Improve the pedestrian environment

Road Projects:

a. Add HOV lanes
b. Implement Intelligent Transportation Systems (ITS)/Traffic management (e.g., change auto travel times, change highway free-flow speed)
c. Add general purpose roadway lanes (e.g., change highway capacities)

Transit:

a. Construct new transit lines
b. Increase service (e.g., change transit headways, increase network connectivity)
c. Upgrade transit service (e.g., change from bus to light rail)
d. Improve accessibility (e.g., change bike/walk access distance to transit stations, change auto access distance to transit stations)

Pricing:

a. Develop tolls and toll roads
b. Implement HOT lanes
c. Increase the cost of parking
d. Change in transit fares
e. Change in auto operation cost

Transportation Demand Management:

a. Promote carpooling, vanpooling, telecommuting and teleconferencing
b. Promote walking and biking
c. Implement employer-based trip reduction strategies

### Examples of Analysis

The following are hypothetical examples to illustrate how ARB staff will review model sensitivity.

Increase Transit Service Frequency

An MPO includes doubling the frequency of transit service in its region in its SCS. The MPO's modeling demonstrates an increase in transit ridership of 30% as a result. Information from the *UCD-UCI Policy Brief on the Impacts of Transit Service Strategies Based on a Review of the Empirical Literature* cites evidence that for every 1% increase in service frequency in an urban area, a corresponding increase in ridership should result in the range of 0.3% to 0.5%[v]. In this example, the expected result would be a 30% to 50% increase in ridership based on empirical literature. The modeled result falls within the expected range, so the model would be considered sufficiently sensitive to the variable of transit service frequency.

Road Pricing

An MPO includes increasing toll road pricing on selected freeway segments by 25% in its SCS. Modeling from the MPO demonstrates a reduction in traffic of 15% on the corresponding roadways, including use of an off-model tool. Information from the *UCD-UCI Policy Brief on the Impacts of Road User Pricing Based on a Review of the Empirical Literature* lists data showing that for every 1% increase in tolls in an urban area, traffic would be expected to decrease within a range of 0.03% to 0.5%[vi]. The expected results would range from a 0.75% to 12.5% decrease. In this example, the modeled result is outside the expected range identified in the literature. Therefore, ARB staff would expect the MPO to provide information to explain its results, including whether other factors are responsible, or if the model is not sufficiently sensitive to road pricing as a variable, how that would affect the GHG targets determination.

Increase Residential Density

An MPO includes increasing the average residential density 25% region-wide in its SCS. The MPO's modeling shows a resulting reduction in VMT of 2.5%. The *UCD-UCI Policy Brief on the Impacts of Residential Density Based on a Review of the Empirical Literature* cite studies that show a range of 0.07% to 0.12% decrease in VMT for every 1% change in the built environment[vii]. The expected decrease in VMT would therefore fall between 1.75% and 3%. In this example, the modeled result falls within the expected range, so the model would be considered sufficiently sensitive to the variable of transit service frequency.

### Sources of Information for Comparison

ARB staff acknowledges that the body of empirical literature applicable to California and the SB 375 process is limited at this point in time. However, academic institutions and other research organizations are showing considerably greater interest in conducting further studies in this area that are applicable to the California experience. In some cases, ARB is funding this research. Therefore, ARB staff expects this part of the analysis to grow more robust over time and provide increasingly relevant information.

ARB staff will rely upon a variety of specific information sources to help inform the sensitivity analysis portion of the evaluation. The information from these sources can be compared to the results of MPOs' sensitivity analyses to determine if the modeled results fall within a range of expected outcomes, or if other factors may be affecting the outputs. These sources include:

University of California, Irvine and University of California, Davis

ARB contracted with researchers at the University of California at Irvine and Davis to identify the impacts on vehicle use and greenhouse gas emissions of key transportation and land use policies, based on the scientific literature. This research provides one step in a long-term process to help strengthen the technical underpinnings of SB 375 and to identify important data gaps and research needs. The research results may be used to help inform development of, and potential improvements to, the models and tools used by MPOs and others for SB 375 implementation. (Source: http://arb.ca.gov/cc/sb375/policies/policies.htm )

California Air Pollution Control Officers Association

*Quantifying Greenhouse Gas Mitigation Measures: A Resource for Local Government to Assess Emission Reductions from Greenhouse Gas Mitigation Measures* was prepared by the California Air Pollution Control Officers Association (CAPCOA) along with the Northeast States for Coordinated Air Use Management, the National Association of Clean Air Agencies, and with technical support from Environ and Fehr & Peers. It primarily focuses on the quantification of project-level mitigation of greenhouse gas emissions associated with land use, transportation, energy use, and other related project areas. (Source: http://www.capcoa.org/wp-content/uploads/2010/11/CAPCOA-Quantification-Report-9-14-Final.pdf )

Regional Targets Advisory Committee

*Recommendations of the Regional Targets Advisory Committee (RTAC) Pursuant to Senate Bill 375, September 2009*, the final RTAC report, includes a section in Appendix A on MPO Travel Demand Models: Sensitivity to Policy Variables and Factors. This information focuses on policy variables which significantly influence travel in a region, and over which local agencies and system operators have some level of control. (Source: http://www.arb.ca.gov/cc/sb375/rtac/report/092909/finalreport.pdf )

Victoria Transport Policy Institute

The Victoria Transport Policy Institute published a document in May 2011 entitled *Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior*. This report investigates the influence that prices and service quality have on travel behavior. It summarizes research on various types of transportation elasticities and describes how to use this information to predict the travel impacts of specific price reforms and management strategies. (Source: http://www.vtpi.org/elasticities.pdf)

## VI. Performance Indicators

Performance indicators are metrics or statistics used to evaluate how well an MPO's proposed RTP and SCS will achieve stated goals in future years compared with current conditions, which in the case of the SCS includes changes in GHG emissions. Performance indicators provide a basis for determining whether the RTP and SCS move a region closer to meeting the GHG targets, as well as meeting other objectives that are important to the region. They are derived from an MPO's modeling outputs, which are driven by the SCS selected by an MPO. It should be noted that, in this document, the term "performance indicators" is not necessarily consistent with the term "performance measures." The latter term is used by MPOs for the evaluation of the performance and effectiveness of the transportation system, policies, and programs[viii] to explain not only regional-level but also community-level changes in outputs.

ARB staff will review an MPO's performance indicators to determine whether they provide supportive, qualitative evidence that the SCS could meet its GHG targets. Specifically, ARB staff will examine whether selected regional performance indicators are directionally consistent with the MPO's modeled GHG emissions reductions, as well as with the general relationships between those indicators and GHG emissions, as identified in the empirical literature.

### Evaluation

ARB staff will review the performance indicators identified below to assess, for the region as a whole, whether the projected regional changes in per capita VMT, land use patterns, and vehicle activity patterns are consistent with the change in GHG emissions.

ARB staff will start with a trend comparison analysis between per capita $CO_2$ emissions and other individual performance indicators. This analysis will depend on the relationships between these indicators and GHG emissions in the empirical literature to inform whether the directional change of the indicators (an increase or decrease) makes sense in light of the anticipated GHG emissions reductions.

A variety of performance indicators are useful to illustrate the impacts of the SCS in the region, including improvement in accessibility, mobility, sustainability, and environmental quality, among others. ARB's evaluation will be limited to a set of performance indicators that provide an understanding of which strategies are directionally related to the changes in GHG emissions. In the transportation modeling system, regional changes can be expected to be reflected in the modeling outputs of passenger VMT, commute modes, residential densities, housing/employment near transit stations, and active commute mode patterns. Depending on regional characteristics, additional performance indicators may be reviewed to explain regional progress in meeting the targets. Examples of regional performance indicators that ARB will review include, but are not limited to, the following:

- Passenger vehicle miles traveled is one of the most direct indicators of a change in GHG emissions. As passenger vehicle travel miles increase, it is expected that the increase of GHG emissions follow a similar trend. ARB staff will examine per capita VMT.

- A change in commute trip mode share provides evidence that GHG emissions will also change. As passenger vehicle mode share decreases and transit/bike/walk mode shares increase, it is expected that GHG emissions would increase. The specific performance indicators are commuter mode share by drive alone, carpool, bus transit, rail transit, bike and walk.

- Residential density is highly correlated with almost all measures of urban sprawl and provides evidence of a change in GHG emissions. Denser residential development tends to increase travel mode shares other than the automobile mode, so that it contributes to regional automobile VMT reduction by fewer trips and/or shorter trip distances. ARB staff will examine the number of housing units per net residential acreage developed, and population per net residential acreage developed.

- Distance of housing and employment from transit stations is a strong measure of evaluating the effectiveness of transit oriented development (TOD) in reducing VMT. The specific performance indicators are percentages of housing units and total employment within ½ mile of transit (all bus and rail) stations.

- Bike and walk trips are a direct measure of the effectiveness of walk access and bike facility infrastructure development, which reduces automobile trips. A change in bike and walk trips through various land use strategies may result in a change in regional GHG emissions. The specific performance indicators are number of bike/walk trips and percentage of bike/walk trip mode share.

**Example of Analysis**

The following is an illustrative example of a trend analysis comparing per capita $CO_2$ emissions to per capita passenger vehicle VMT.

In a hypothetical MPO, the trend of VMT reductions, in light of the regional transportation and land use strategies, is very similar to the per capita $CO_2$ reductions for that region. Per capita VMT decreases from 2005 to 2020 and slightly increases by 2035. Per capita VMT decreases by 5%, 12% and 10% from the base year of 2005 for 2008, 2020 and 2035, respectively. Meanwhile, per capita $CO_2$ emissions decrease by 4%, 13% and 12% from the base year of 2005 for 2008, 2020 and 2035, respectively. As expected, these numbers show that the per capita $CO_2$ emissions follow the same trend directionally as per capita VMT. Therefore, this performance indicator (change in automobile VMT per capita) provides supportive, qualitative evidence demonstrating that the MPO's modeled change in $CO_2$ per capita for the region is consistent with the model output and the relationships shown in the empirical literature.

## VII. Next Steps

ARB's methodological approach for evaluating an SCS, as described in this document, reflects the current state of technical tools used by the MPOs for regional transportation planning. Although these models have been used for decades to evaluate transportation demand and mobility, they were not designed to evaluate the GHG emissions associated with specific land use and transportation strategies that are at the heart of an SCS. With the passage of the Sustainable Communities Act, model developers are beginning to develop the next generation of modeling tools that will allow for improved and tailored analysis of GHG related land use- and transportation-related strategies. ARB expects to be at the forefront of these efforts so that new tools can be applied directly to the development of future RTPs/SCSs that achieve the targets consistent with sustainable land use and transportation strategies.

Looking ahead, ARB will work with MPOs and model developers to more effectively account for Sustainable Communities-related policies within the model itself in an integrated manner, rather than through the use of the current patchwork of models and off-model tools. As a first step, ARB intends to hold a symposium to evaluate the current state of transportation modeling for use in SCS development, and to inform the development of new tools and models for use in future RTP/SCS development.

# APPENDIX A

**ARB's Evaluation Methodology: Key Questions, Evaluation Elements and Example Technical Questions**

The following are examples of specific types of information that ARB will request after gaining a basic understanding of the models that an MPO used for SCS development. Information requests will be customized to the region.

| Questions | Evaluation Element | Examples of Specific Questions |
|---|---|---|
| Did the MPO use adequate modeling and analysis tools to evaluate the SCS? | • Models<br>• Model Inputs<br>• Sensitivity Analysis | 1. Explain the basic components of your model and four-step process.<br>2. How were the models calibrated and validated? What indicators were used for the model calibration and validation?<br>3. How were the models peer-reviewed? How frequently was this done? Provide a list of the model validation analyses you performed.<br>4. How did you handle external, inter-regional trips? If you did not use the approach recommended by RTAC (exclude 50% of inter-regional trips), then what approach did you use, and why?<br>5. How did you incorporate the latest scientific findings (e.g., human behavior, elasticity, etc.) into your models?<br>6. How were the model outputs converted into GHG emissions? What models/tools did you use for this purpose?<br>7. What were the key limitations on current models and tools?<br>8. What are the plans to update and develop new models?<br>9. What criteria did you use to decide when off-model tools were necessary?<br>10. If you have used any off-models tools, how were they used, and for which strategies?<br>11. How and what smart growth policies (4D, bike and walk, etc.) were quantified in the current models?<br>12. For smart growth policies not quantified in models, how did you quantify their GHG benefits?<br>13. How were model sensitivity analyses conducted? Provide the list of model sensitivity analyses that you performed.<br>14. What policies and strategies were modeled with reasonable |

| | | |
|---|---|---|
| | | sensitivities? How would you define ‘reasonableness’ with respect to sensitivities?<br>15. What policies and strategies were modeled with limited sensitivities? If models had limited sensitivity to the policies and strategies, how did you make adjustments?<br>16. Have you compared your model sensitivity analysis results, such as elasticity, to the empirical literature findings? How do your sensitivity analysis results compare to the results reported in empirical literature? |

| | | |
|---|---|---|
| Does the modeling adequately reflect the region’s projections? | • Models<br>• Model Inputs<br>• Performance Indicators | 1. What were the sources of transportation and land use model inputs?<br>2. Are model input data verifiable with publicly available data?<br>3. How were the model inputs validated or verified? What guidance did you use for the validation or verification? Provide ARB with the guidance used.<br>4. How were economic changes (e.g., recession) reflected? How did you verify the economic changes?<br>5. How were the model outputs validated or verified? What guidance did you use for the validation or verification? Provide ARB with the guidance used.<br>6. What key land use modeling inputs impact GHG reductions?<br>7. What key transportation modeling inputs impact GHG reductions?<br>8. From among the list of performance measures adopted by your Board, which did you use to explain the GHG reductions? Did you use any others that were not on the list? |
| Are MPO-adopted SCS strategies, and the SCS as a whole, consistent with projected GHG reductions, including consideration of reasonable timing, adequate resources and types of projects? | • Models<br>• Performance Indicators<br>• Sensitivity Analysis | 1. What key indicators best explain the impacts of the SCS?<br>2. What level of funding is assumed in SCS development, implementation and model improvement, and in what timeframe?<br>3. GHG reduction targets are based on a base year of 2005. If the MPO used RTP base year different from 2005, how did you calculate or make adjustments to demonstrate target achievement based on 2005? |

| | | |
|---|---|---|
| What is the relative contribution of specific SCS strategies or groups of strategies to the total projected GHG reduction? | • Models<br>• Model Inputs<br>• Performance Indicators<br>• Sensitivity Analysis | 1. Which strategies were incorporated into the SCS? How did the MPO quantify their GHG-reduction benefits (e.g., within the model, off-model adjustments)?<br>2. Is it possible to quantify GHG contributions by individual policy or strategy (e.g., Land Use, TDM, TSM, Pricing, others)?<br>3. How and what smart growth policies (4D, bike and walk, etc.) were quantified in the current models?<br>4. Did the MPO compare model sensitivity analysis results to the empirical literature findings such as elasticity? How do the MPO's sensitivity analyses compare to the results reported in empirical literature? |

## MPO Data Request for RTP/SCS Key Modeling Parameters

The following are examples of the types of data that ARB may request from an MPO. Data requests will be customized to the region.

| Modeling Parameters | 2005 (if available) | 2008 (base year) | 2020 (With Project) | 2020 Without Project) | 2035 (With Project) | 2035 (Without Project) | Data Source(s) |
|---|---|---|---|---|---|---|---|
| **DEMOGRAPHIC** | | | | | | | |
| Total population | | | | | | | |
| Persons per household | | | | | | | |
| Total number of households | | | | | | | |
| Total number of jobs | | | | | | | |
| Average unemployment rate (%) | | | | | | | |
| Average household income ($) | | | | | | | |
| **LAND USE** | | | | | | | |
| Total housing units | | | | | | | |
| Total dwelling units | | | | | | | |
| Total acreage developed | | | | | | | |
| Total acreage available for new development | | | | | | | |
| Percent housing within 1/4 mile of transit stations | | | | | | | |
| Percent housing within 1/2 mile of transit stations | | | | | | | |
| Percent employment within 1/4 mile of transit stations | | | | | | | |
| Percent employment within 1/2 mile of transit stations | | | | | | | |
| Multifamily dwelling units | | | | | | | |
| Single family detached dwelling units | | | | | | | |
| Single family attached dwelling units | | | | | | | |
| Acreage of land zoned (used and available) for mixed use | | | | | | | |
| Average density - dwelling units per developed acre | | | | | | | |
| **TRIP DATA** | | | | | | | |
| Number of trips by trip purpose | | | | | | | |
| - Home-based work | | | | | | | |
| - Home-based school | | | | | | | |
| - Home-based shopping | | | | | | | |
| - Home-based others | | | | | | | |
| - Non home-based other | | | | | | | |
| Average auto trip length (miles) | | | | | | | |

| Modeling Parameters | 2005 (if available) | 2008 (base year) | 2020 (With Project) | Without Project) | 2035 (With Project) | (Without Project) | Data Source(s) |
|---|---|---|---|---|---|---|---|
| Average walk trip length (miles) | | | | | | | |
| Average transit trip length (miles) | | | | | | | |
| Average auto travel time (minutes) | | | | | | | |
| Average walk travel time (minutes) | | | | | | | |
| Average transit travel time (minutes) | | | | | | | |
| Average travel time & trip length for commute by mode | | | | | | | |
| **PERCENT PASSENGER TRAVEL MODE SHARE** | | | | | | | |
| SOV | | | | | | | |
| HOV | | | | | | | |
| HOT | | | | | | | |
| Public transit (Regular Bus) | | | | | | | |
| Public transit (Express Bus) | | | | | | | |
| Public transit (BRT) | | | | | | | |
| Public transit (Rail) | | | | | | | |
| Non-Motorized: Bike | | | | | | | |
| Non-Motorized: Walk | | | | | | | |
| **CO2 AND VEHICLE MILES TRAVELED** | | | | | | | |
| Total CO2 emissions per weekday for passenger vehicles (ARB vehicle classes LDA, LDT1, LDT2, and MDV) (tons) | | | | | | | |
| Total Internal CO2 emissions per weekday for passenger vehicles (tons) | | | | | | | |
| Total IX / XI trip CO2 emissions per weekday for passenger vehicles (tons) | | | | | | | |
| Total XX trip CO2 emissions per weekday for passenger vehicles (tons) | | | | | | | |
| **VEHICLE MILES TRAVELED** | | | | | | | |
| Total VMT per weekday for passenger vehicles (ARB vehicle classes of LDA, LDT1, LDT2 and MDV) (miles) | | | | | | | |
| Total internal VMT per weekday for passenger vehicles (miles) | | | | | | | |
| Total IX/XI VMT per weekday for passenger vehicles (miles) | | | | | | | |
| Total XX VMT per weekday for passenger vehicles (miles) | | | | | | | |

| Modeling Parameters | 2005 (if available) | 2008 (base year) | 2020 (With Project) | 2020 Without Project) | 2035 (With Project) | 2035 (Without Project) | Data Source(s) |
|---|---|---|---|---|---|---|---|
| **CONGESTED TRAVEL MEASURES** | | | | | | | |
| Congested weekday VMT on freeways (miles, V/C ratios >1.0) | | | | | | | |
| Congested VMT on all other roadways (miles, V/C ratios >1.0) | | | | | | | |
| **TRANSPORTATION SYSTEM** | | | | | | | |
| Freeway general purpose lanes –- mixed flow, auxiliary, etc. (lane miles) | | | | | | | |
| Freeway managed lanes--HOV, HOT, Tolled, etc. (lane miles) | | | | | | | |
| Major Arterial / Expressway (lane miles) | | | | | | | |
| Minor Arterial (lane miles) | | | | | | | |
| Collectors (lane miles) | | | | | | | |
| Locals (lane miles) | | | | | | | |
| Regular transit bus operation miles | | | | | | | |
| Bus rapid transit bus operation miles | | | | | | | |
| Express bus operation miles | | | | | | | |
| Transit rail operation miles | | | | | | | |
| Bike lane miles | | | | | | | |
| Miles of sidewalk | | | | | | | |
| **INVESTMENT** | | | | | | | |
| Highway capacity expansion ($) | | | | | | | |
| Other road capacity expansion ($) | | | | | | | |
| Transit capacity expansion ($) | | | | | | | |
| Bus transit capacity expansion ($) | | | | | | | |
| Transit operations ($) | | | | | | | |
| Rail transit operations ($) | | | | | | | |
| Bike and pedestrian projects ($) | | | | | | | |
| Other ($) | | | | | | | |
| **TRANSPORTATION USER COSTS AND PRICING** | | | | | | | |
| Vehicle operating costs ($ per mile) | | | | | | | |
| Gasoline price ($ per gallon) | | | | | | | |
| Parking price ($ per day) | | | | | | | |
| Toll price ($) | | | | | | | |
| Congestion price ($ per mile) | | | | | | | |

# APPENDIX B

## Comparison of MPO Modeling Practices in the Nation[ix]

| Common practices | Differing practices |
|---|---|
| Forecasts of population, households and employment | About half of MPOs also forecast one or more of the following: household size, automobile ownership, and income. |
| The modeled region is divided into Transportation Activity Zones. The zone system is mapped in a GIS database. | The number of TAZs in a region varies from several hundred to several thousand, depending on the region's size. |
| Transportation supply is represented through highway and transit networks mapped in a GIS database. | Highway networks range in size from 4,200 links for small MPOs to more than 20,000 for large MPOs. The larger the MPO, the more likely it is to have complete representation of transit routes and service on the transit network. |
| Trip generation is used to estimate how many trips are expected to be made to and from each TAZ. | Trips for different purposes, such as work, school, shopping, and commercial transport, are estimated. As many as nine trip activity categories are currently used in MPO models; smaller MPOs are more likely to use fewer activity categories. |
| Trip distribution—the process of determining the number of trips between each pair of zones—is accomplished primarily with a gravity model. | Destination-choice models are used by 11 MPOs for trip distribution. Such a model can take into account differences in circumstances that influence travelers' destination choices, which are poorly accounted for in a gravity model. |
| Mode choice is the allocation of trips between automobiles and public transit. Within automobile travel, there is allocation between drivers and passengers; within public transit, there may be allocation among local bus, express bus, and various rail options. | Some MPOs include bicycle and walking trips in their mode-choice model. More than 90 percent of large MPOs reported using a mode-choice model, while 25 percent of small MPOs reported using such a model. |
| Assignment is used to allocate trips to actual routes in the transportation network. | Many smaller MPO regions have little traffic congestion and minimal transit service, and MPOs may assign average daily (24-hour) travel. More complex regions with traffic congestion and extensive transit operations model travel by time periods within the day to better account for the effects of congestion on route choice. Among large MPOs, 75 percent assign travel for at least two and as many as five time periods. |

## ENDNOTES

[i] Federal Highway Administration, “The Travel Model Validation and Reasonableness Checking Manual,” Second Edition, September 2010.

[ii] Ibid.

[iii] California Transportation Commission, “2010 California Regional Transpiration Plan Guidelines,” April 2010.

[iv] California Air Resources Board, “Recommendations of the Regional Targets Advisory Committee (RTAC) Pursuant to Senate Bill 375,” (http://www.arb.ca.gov/cc/sb375/rtac/meetings/050509/mpoassessmentupdate.pdf), Accessed on May 27, 2011

[v] Handy, et al., “Policy Brief on the Impacts of Transit Service Strategies Based on a Review of the Empirical Literature,” University of California, Irvine and Davis, 2010.

[vi] Spears, et al., “Draft Policy Brief on the Impacts of Road User Pricing Based on a Review of the Empirical Literature,” University of California, Irvine and Davis, 2010.

[vii] Boarnet, et al., “Draft Policy Brief on the Impacts of Residential Density Based on a Review of the Empirical Literature,” University of California, Irvine and Davis, 2010.

[viii] California Transportation Commission, “2010 California Regional Transportation Plan Guidelines,” http://www.catc.ca.gov/programs/rtp/2010_RTP_Guidelines.pdf, Accessed on May 27, 2011.

[ix] Wachs, Martin, et al., “Metropolitan Travel Forecasting: Current Practice and Future Direction,” Washington, D.C., Transportation Research Board, National Academies, 2007.