Measuring Progress toward Transportation GHG Goals

Required Actions for Successful SB 375 Implementation

Juan Matute
Director, UCLA Luskin Center Climate Change Initiative
jmatute@ucla.edu

February 2011

Working Paper

Abstract:

The State of California seeks to induce per capita reductions in regional greenhouse gas (GHG) emissions from transportation by setting modeling targets for regional transportation and land use plans. Key to the success of SB 375 are accurate, valid models which are capable of forecasting the effects of transportation and land use policies on future greenhouse gas emissions. Current models are not capable of meeting the regulatory requirements of SB 375. In this White Paper, I discuss the models, evaluation methods, and data required to improve California's ability to successfully implement its SB 375 regional greenhouse gas reduction policy.

Funding for this White Paper was provided by the UCLA Luskin Center for Innovation and the University of California Institute of Transportation Studies Multi-Campus Research Program and Initiative on Sustainable Transportation.

Contents

List of Abbreviations

AB	Assembly Bill
APS	Alternative Planning Strategy
ARB	(California) Air Resources Board
BMP	Best Management Practice
CEMDAP	Comprehensive Econometric Micro-simulator for Daily Activity-travel Patterns
CTC	California Transportation Commission
EMFAC	EMission FACtors (emissions model)
GHG	Greenhouse Gas
MOBILE	EPA emissions model
MOVES	Motor Vehicle Emissions Simulator (emissions model)
MPO	Metropolitan Planning Organization
PECAS	Production, Exchange, and Consumption Allocation System
RHNA	Regional Housing Needs Allocation
RHNP	Regional Housing Needs Plan
RTAC	Regional Targets Advisory Committee
RTP	Regional Transportation Plan
SB	Senate Bill
SCS	Sustainable Communities Strategy
VHO	Vehicle Hours Operating
VMT	Vehicle Miles Traveled
VSP	Vehicle Specific Power

Part I – SB 375: Policy context, needs, and evaluation

Introduction to California's SB 375

With SB 375, the State of California has levied a performance-based GHG reduction target on regional governments, both to lessen the state's GHG reduction burden and to induce the adoption of complimentary policies. Regional and local governments will implement land use and transportation strategies under their unique jurisdictional control in order to achieve state prescribed reduction targets in GHG emissions from cars and light trucks. In adopting SB 375, the California State Legislature found that adjustments to land use and transportation policy were needed to compliment state efforts to reduce GHG emissions using new vehicle technology and low carbon fuels (California Sen. Bill 375 § 1 (c), 2008). In the AB 32 Scoping Plan, California's plan to meet its target to reduce GHGs to 1990 levels by 2020, the California Air Resources Board (ARB) sought additional reductions from regional and local land use and transportation planning.

When implementing SB 375, regional and local governments will implement policies that reduce per capita GHG emissions from transportation while addressing previous regulation that has led to market failures and GHG inefficiencies in the transportation sector. In this paper, I outline and evaluate the SB 375 compliance process, identify barriers to policy success, and recommend actions to improve policy effectiveness.

The SB 375 Target-Setting Process

The SB 375 legislation did not prescribe targets, rather it left this task to the ARB, with inputs from an appointed Regional Targets Advisory Committee (RTAC). The RTAC, a group of 21 environmental, business, transportation, and social equity stakeholders met 13 times over 8 months. This group, guided by principles such as minimizing the administrative burden of implementation; encouraging regional and sub-regional cooperation; maximizing co-benefits and social equality; and using metrics to measure cost effectiveness, made official recommendations to the ARB on SB 375 target-setting and implementation. Among their recommendations are:

- Concerning the target-setting process
    - The ARB and regions should exchange technical information. Through this exchange, regions can learn about best policy practices from other regions and the effects of future auto fuel efficiency and fuel standards on transportation GHGs. The ARB can learn more about which emissions reduction scenarios are feasible, and gain technical experience needed to evaluate regional modeling methods.
    - Information used in target-setting should be made public so that the diverse group of stakeholders interested in implementation can evaluate and understand targets.
- Concerning principles and tools used to set targets:
    - Regions "should do everything it feasibly can do to reduce greenhouse gas emissions" (Regional Targets Advisory Committee 2009, 27). The ARB had previously stated in the AB 32 Scoping plan that SB 375 targets would be the most "ambitious achievable" and the RTAC committee made recommendations on how this notion could be applied to SB 375 target-setting.
    - Empirical studies should be used as a basis for deriving ranges of GHG emissions reduction effectiveness for specific policies. This data should be used in a Best Management Practice list and evaluation tool and in evaluating a region's emissions reduction plan.
    - Models should be used by the ARB in setting targets and by regions in demonstrating target compliance. Effectiveness used in off-model tools, such as the Best Management Practices tool and post-processors, should correspond with model results. Regions should assess models for shortcomings related to SB 375 implementation and engage in a multi-year model improvement program.
    - Assumptions used as model inputs should be identified in a transparent manner. In cases where assumptions should be standardized statewide (e.g. fuel prices) the ARB should recommend values.
    - Best management practice tools should be used to set targets; to develop GHG reduction strategies; as an option for small MPOs to demonstrate target compliance; by the ARB to determine the accuracy of SCS submissions, and as a tool for the public for use in evaluating strategies. BMP would take inputs on policies and the area being analyzed and produce VMT and GHG reduction estimates. In the long term, BMP tools would be used in scenario planning workshops and in cases where full model runs are not practical.
    - The 2020 and 2035 target metrics should be expressed as a percent reduction in per capita GHG emissions from 2005 levels.
    - GHGs from vehicle trips between regions should be split 50/50 between origin and destination regions.

Using these recommendations, the ARB set regional GHG targets on September 30th, 2010. The ARB must update the regional targets every 8 years based on a broad set of factors used in the creation of the initial target (such as how ambitious and achievable transportation and land use policies can be used to reduce GHG emissions). The ARB may also elect to update the regional targets every 4 years based on a limited set of factors having to do with vehicle fuel efficiency, low carbon fuels, and other AB 32[1] implementation measures.

California's SB 375 Sustainable Communities Strategy Compliance Process

MPOs must incorporate their regional GHG reduction target into their next Regional Transportation Plan development process. The Regional Transportation Plan (RTP) is a 30-year visioning and planning exercise to establish priorities for transportation infrastructure, policies, programs, and transit service in the context of environmental, economic, and quality of life goals. Federal regulations require regions to adopt an RTP approximately every 4 years. SB 375 aligns the RTP with the state of California's Regional Housing Needs Allocation (RHNA) process. Through this process, cities within regions are assigned new housing growth based on anticipated changes in regional housing demand.

In advance of this regional planning process, the MPO must share information with the ARB regarding the technical methodology it plans to use to forecast GHG emissions from its Sustainable Communities Strategy (SCS) or Alternative Planning Strategy (APS). The ARB must comment on the technical methodology an MPO plans to use to quantify the GHG reduction effects from its SCS or APS:

[1] California's Global Warming Solutions Act of 2006, establishes a greenhouse gas reduction target of 1990 levels by 2020

> … the metropolitan planning organization shall submit a description to the state board of the technical methodology it intends to use to estimate the greenhouse gas emissions from its sustainable communities strategy and, if appropriate, its alternative planning strategy. The state board shall respond to the metropolitan planning organization in a timely manner with written comments about the technical methodology, including specifically describing any aspects of that methodology it concludes will not yield accurate estimates of greenhouse gas emissions, and suggested remedies. The metropolitan planning organization is encouraged to work with the state board until the state board concludes that the technical methodology operates accurately.
>
> - California Gov't Code § 65080 (b)(2)(J)(i)

The SCS and APS are new documents which must be produced as part of the regional planning process. The Regional Targets Advisory Committee recommended that this technical methodology be an integrated land use, transportation, and emissions model (Regional Targets Advisory Committee 2009). Realizing that small MPOs may lack models capable of forecasting policy effects, the RTAC recommended allowing the use of a Best Management Practice tool for the first round of SB 375 implementation (RTAC Recommendations 21).

As part of the regional planning process, the MPO will evaluate and select a bundle of policies designed to reduce GHG emissions driving and increase the percentage of trips made by transit, walking, and biking. Such policies could include:

- Transportation Strategies
  - Parking pricing and other strategies which increase terminal costs for private vehicle use and shift demand for trips to carpools, transit, biking, or walking.
  - Pricing road users based on the distance they drive (VMT pricing), or the delay impact the user has on other roadway users (congestion pricing), in order to increase vehicle operation costs, decrease trip distances, shift trips to alternative modes, smooth vehicle flow, and/or deter trips.
  - Employer trip reduction strategies such as parking-cash out which decrease the percentage of employees which drive alone to work.
  - Enhancements to bicycle and pedestrian infrastructure which increase the proportion of trips made on foot or on bicycle.
  - Improvements to transit service in order to increase the proportion of trips made via transit.
  - Transportation system improvements and vehicle operation improvements which reduce GHG emissions per mile traveled.

  - Local or regional policies which encourage the adoption of more fuel efficient and clean field automobiles
- Land Use Strategies
  - Residential density in order to decrease the spatial footprint of a region, thereby concentrating trip origins and destinations closer to each other than in a "sprawl" scenario.
  - Concentration of residential development near transit (Transit Oriented Development)
  - Concentration of residential, retail, and commercial land uses within developments or neighborhoods to increase the proportion of trips captured by the local area.
  - Improved integration between land use and transportation policies to encourage network connectivity
  - Concentration of new development in regional centers or urban centers, where existing trip attractors are more accessible. Funding for affordable housing in such areas.

The polices an MPO elects to pursue will be incorporated into an SCS or APS which achieves the region's transportation GHG reduction target. The MPO will use its model or the Best Management Practices tool to forecast regional GHG emissions associated with plan implementation. MPOs currently utilize integrated land use, transportation, and emissions models in their Regional Transportation Plan process. These models are the primary tool MPOs use to forecast transportation infrastructure needs, congestion, and criteria pollutant emissions resulting from plan implementation to determine compliance with the U.S. Clean Air Act. SB 375 adds a separate state compliance target for GHG emissions.

If the MPO forecasts that GHG emissions in 2020 and 2035 will achieve the ARB reduction targets, then it can submit a Sustainable Communities (SCS) Strategy to the ARB for approval. If the MPO forecasts that GHG emissions in 2020 and 2035 will fail to achieve the ARB reduction targets, then it can revise its plan until it will achieve these targets, or it can submit an Alternative Planning Strategy (APS) to the ARB for approval.

After the MPO adopts an SCS or APS, it must then submit it to the ARB for approval. The ARB must review the submitted SCS or APS and approve or reject it based on whether or not the implemented strategy would achieve the GHG reduction targets it has set for 2020 and 2035.

> If the state board determines that the strategy submitted would not, if implemented, achieve the greenhouse gas emission reduction targets, the metropolitan planning organization shall revise its strategy or adopt an alternative planning strategy, if not previously adopted, and submit the strategy for review pursuant to clause (ii). At a minimum, the metropolitan planning organization must obtain state board acceptance that an alternative planning strategy would, if implemented, achieve the greenhouse gas emission reduction targets established for that region by the state board.
> California Gov't. Code. § 65080 (b)(2)(I)(iii)

One goal of policymakers is that regions will strive to submit and have approved an SCS as opposed to an APS. The SCS is a section of the RTP, which is used in federal funding decisions, and is constrained to projects that are reasonably expected to receive funding. The APS is separate from the RTP and is not fiscally constrained. After an MPO adopts an ARB-approved SCS or APS, residential and mixed-use residential projects consistent with the plan are granted an exemption from analyzing the project's regional GHG emissions and the project's impacts on the regional transportation network as part of the CEQA review process. Additionally, Transit Priority Projects (generally residential and mixed-use residential projects within ½ mile of a rail or BRT station or within ¼ mile of a regular bus line) can be exempt from analyzing local traffic impacts and off-site alternatives as part of the CEQA review process. Sustainable Communities Projects (Transit Priority Projects which meet additional criteria, including a housing affordability component) can be exempt from CEQA review process and instead perform a streamlined Sustainable Communities Environmental Assessment.

Evaluating The Success of SB 375

Before a region adopts its first SCS or APS, GHG emissions from transportation will be evaluated at the level of the individual project. Not only is individual analysis a piecemeal approach to solving a regional problem, strategies that appear to be effective in reducing project-level GHG emissions actually increase GHG emissions when implemented on a regional scale. GHG emissions from an individual residential and retail project will be reduced when the number of housing and retail units is reduced. However, regional per capita GHG emissions are lower in areas which have higher density and origins and destinations are closer together. By adopting an APS or SCS, a region will move the bulk of transportation GHG analysis and management from the individual project to the regional planning process. The regional level will prove to be a superior geographic scale for transportation GHG management than the project level.

Evaluating the success of SB 375 as a policy which moves regions to adopt policies and meet GHG reduction targets is more difficult. Successful statutory compliance with SB 375 does not mean an MPO will achieve its GHG reduction targets in 2020 or 2035. There are three main indicators which will determine the success of SB 375. The first is statutory compliance: are MPOs able to demonstrate that their plan will allow the region to achieve its 2020 and 2035 transportation GHG reduction targets? The second measure of success is whether or not an MPO and its local governments implemented the Strategy. The third is a measure of policy success that can only be evaluated in 2020 (and 2035): did an MPO with an approved and implemented SCS or APS actually achieve its 2020 (and 2035) GHG reduction targets?

Some MPOs which are successful in implementing a series of approved SCS (success with measures 1 and 2) will fail to achieve their 2020 or 2035 GHG reduction targets. This could happen for one of two reasons. First, deficiencies in the model that the MPO and ARB used to evaluate the regional plan's ability to achieve the target could produce an inaccurate forecast. If the model misestimates the effects of a policy or non-policy factor, either individually or in a bundle, it could produce an inaccurate forecast.

The second reason is that the region failed to meet its target as a result of some factor exogenous to the model and/or outside of MPO control. Two key factors which influence regional transportation activity and GHG emissions but are outside of MPO control are fuel prices and incomes. If either one of these factors deviate from the model assumptions the MPO used to forecast SCS GHG performance, this could result in GHG emissions that are higher or lower than forecasts. Models must be capable of differentiating factors beyond MPO control and policies implemented in order to determine the success of SB 375.

To set valid "ambitious, achievable" GHG targets and create and evaluate SCS submissions, the ARB and MPOs require models which are sensitive to the full suite of policies which regions might implement, consistent among regions, accurate in their forecasts, and validly express the relationship between specific policies and GHG emissions. Current models do not meet these criteria.

Importance of Model Accuracy for SB 375 Implementation

The success of SB 375 will largely depend on the accuracy of models – the ability of these models to forecast regional GHG emissions with an acceptable margin of error. The draft regional targets proposed by the ARB for the four largest MPOs are 7 to 8% of regional GHG from transportation (California Air Resources Board 2010). Even a 1% forecast error could cause a region to miss its per capita reduction target by 15%.

To be accurate, a model must be capable of summing the GHG effects of various strategies a region will implement with its SCS, existing factors such as current land use allocations and the transportation network, and other factors known to influence travel activity, like future fuel prices. To do this, the model must be "sensitive", or capable of forecasting the effects of each one of these factors.

For years, most comprehensive models used in regional planning have been sensitive to macro-scale land use allocation and the transportation network. The traditional four-step transportation model, a basic model still used by` many MPOs to forecast road-building needs, uses this data to forecast trips and the general paths they will take. In these models, the decision-making process that cause individuals to choose a specific mode (transit or car) and routing is greatly simplified to facilitate modeling.

While some SCS and APS policies may result in new transportation network infrastructure or change to land uses, many policies will influence an individual's decision-making process in ways that are not captured by traditional four-step models. In order to accurately capture the GHG reduction effects of policies which influence trip related decision-making, a model must be capable of forecasting the direction and magnitude of the policy's future effects on travel activity and transportation GHG. Model developers need information from empirical studies of policy implementation in order to forecast the magnitude of policy effects.

Furthermore, the effects of individual policies may differ in between regions, based on local conditions that influence travel behavior. For instance, improvements to bicycle infrastructure may be more effective in a relatively flat region with good weather than a hilly region with weather conditions not conducive to bicycle riding. Additionally, individual policies may differ in effectiveness when implemented with complementary policies. For instance, the combined effect of improvements to bicycle infrastructure and provision of additional transit service may be greater when implemented together rather than individually because people will bring bikes `to transit.

Current State of Model Accuracy in California

Integrated regional land use and transportation models are developed and implemented by individual MPOs. As such, the capabilities of models differ between MPOs. In the spring of 2009, the Sacramento Area Council of Governments surveyed modeling capabilities for the 18 California MPOs which must achieve regional GHG targets. MPOs self-assessed how their models responded to the various strategies which an MPO might choose to pursue under SB 375 implementation. At the time of the survey, no region had a model which was reasonably sensitive to all policies or factors which an MPO might choose to pursue. Several regions had plans to improve the models, and only SCAG and SANDAG had improvements planned or under development to make the regional model "reasonably sensitive" to all potential policies (Regional Targets Advisory Committee 2009, 5)

Even in instances where the assessment indicated that a model is "reasonably sensitive" to an implementation strategy, the model may not be completely accurate in forecasting policy outcomes. The assessment's standard for "reasonable sensitivity" is defined as follows:

> "Reasonable sensitivity of a model to a key factor means that variations in the key factor which are used as inputs to or parameters within the model result in variations in model output measures which:
>
> a) fall within the range of observed variation reported in research literature, academic consensus, or peer consensus;
>
> b) match variations in observed travel or land use data within tolerances established for modeling by the MPO and those in published model validation guidelines by state and federal organizations (e.g. FTA New Starts, CTC Guidelines, etc); or
>
> c) would be expected based on travel behavior or land economics theory, if a range of observed variation is not known, or no consensus exists as to the acceptable range of observed variation."
>
> (Regional Targets Advisory Committee 2009, 1)

The "range of observed variation reported in research literature, academic consensus, or peer consensus" can be large, and the ARB may lack information on where in this range the effectiveness of a particular regional policy implementation may fall. Policy effectiveness is sensitive to local conditions and the degree of implementation. Thus, when MPOs are creating plans and the ARB is assessing the models, the ARB will expect a range of GHG reduction effects from a nearly identical policy. To set targets and evaluate models, the ARB must have sufficient information on which local factors influence policy effectiveness. Without this information, the ARB will have no way to critically evaluate differences in MPO expectations of policy effectiveness: one MPO may predict a policy will reduce GHG emissions by 0.5% while another MPO predicts the same policy will reduce GHG emissions by 0.2%.

Model Validity & Exogenous Factors

Models can be accurate predictors without being valid predictors, and a lack of validity can jeopardize the effectiveness of SB 375 as a policy. Accuracy is a test of whether a model's output is reliable in predicting future travel activity and GHG emissions. The accuracy of a travel model is assessed based on its ability to calculate observed transportation outcomes, such as traffic counts for a specific link or total VMT for a region, for a previous year using input data from that year (a process known as backcasting). Models can be correct in predicting effects without being correct about the causes.

Validity is a test of whether the internal capabilities of a model are accurate: does the model correctly attribute predicted effects to the policies or factors that cause them? While legal compliance with SB 375 may only require that models are accurate, policy success requires that models are also valid. Even when a model is accurate, if it lacks validity policymakers and researchers will be unable to:

- analyze specific policies for their GHG emissions reduction effectiveness and cost effectiveness and identify and promote best practices,
- design appropriate technical assistance programs given regional variations
- assess whether the policies implemented under an SCS or some other factors are responsible for observed changes in GHG emissions from transportation,
- and determine whether observed policy effects may be repeatable in the future.

Models are statistical predictions of future conditions based on current conditions and known information about changes which will affect future conditions. Integrated land use and transportation models are built using predictions of how a policy or factor will influence travel activity or emissions from multiple regression models. Multiple regression models are subject to a statistical phenomenon known as multicollinearity, which occurs when two or more of the inputs used in models are highly correlated.

The result of multicollinearity is that a model may misrepresent the effects of an individual policy or factor without affecting the model's ability to accurately predict future regional emissions. For instance, adults ages 25-34 may walk more relative to adults 51-65, reducing their per capita GHG emissions. But, adults ages 25-34 might also live in more compact neighborhoods relative to adults 51-65. Those living in compact neighborhoods have lower per capita GHG emissions. If age is highly correlated to neighborhood density, then it may be difficult for researchers and models with limited data to disentangle the effects of age and neighborhood density on GHG emissions. Proper attribution of the statistical relationship is important to SB 375-related policymaking. While policymakers cannot affect resident age, they can affect residential densities.

To remedy the statistical phenomenon of multicollinearity and produce valid models, researchers must collect more data: more observations of policy effects, and more information surrounding the local conditions that may have affected those observations. Required data collection is discussed further in recommendation #6 in Part II of this paper.

Even with a valid model, exogenous factors which are not captured by models and/or not subject to regional control may jeopardize the policy success of SB 375. Even if an MPO and the ARB predict that an SCS or APS will allow a region to achieve its GHG targets, the region still may fail to achieve these targets as a result of factors not included in the model or outside of MPO control. Exogenous factors influence travel activity and GHG emissions but are not captured by models. Exogenous factors include both factors that are known to affect travel and are not captured by models and factors with previously unknown effects on travel activity. Factors outside of regional control include changes in incomes and fuel prices, which significantly affect travel activity.

In many cases, factors outside of regional control are also exogenous. Only 7 of the 18 region's models were reported as being "reasonably sensitive" to income (Regional Targets Advisory Committee 2009, 6). Only 3 of the 18 region's models were reported as being "reasonably sensitive" to gasoline prices and auto operating cost.

Policymakers and researchers can reduce the potential of exogenous factors to jeopardize the policy success of SB 375 by improving a region's ability to quickly incorporate new modeling capabilities and by conducting additional empirical evaluation to understand the effects that different factors have on travel activity. The activities and investment needed to perform these two tasks are detailed in recommendations 4 and 5 in Part II of this paper.

Factors outside of regional control will vary in ways not expected not expected by the ARB, MPOs, or researchers. MPOs and the ARB must develop the ability to control for these factors in order to determine whether an SCS would have allowed the region to meet its targets had the unexpected changes not occurred. This ability, known as "controlling," requires additional model development and empirical evaluation.

Critical Analysis of SB 375

The ARB is charged with establishing regional reduction targets, determining the accuracy of a methodology and whether or not an implemented plan would achieve reduction targets.

Compromises in target-setting process

The ARB is currently engaged in establishing regional reduction targets. To set regional targets, the ARB is using the RTAC recommendations, known information about policy effectiveness from empirical studies and peer-reviewed literature, and future expected vehicle adoption (Pavley I & II) and fuel composition (Low Carbon Fuel Standard). While the ARB can update the targets every four years based on new information on fuel efficient vehicles, low carbon fuels, and other AB 32 implementation measures, the targets cannot be updated based the broader set of criteria used in initial target-setting until 2018.

In setting targets, the ARB should seek recognize that an equal reduction burden is different from an equal reduction target. Because of regional differences, some regions will be able to implement effective GHG reduction strategies more easily than other regions. The ARB should seek to normalize the regional reduction burden, rather than the regional reduction target percentage. A region's burden to meet a given target will vary based on many criteria, including but not limited to the region's population growth rate and the pace at which it adopts new fuel efficient and low carbon fueled vehicles. To properly evaluate and normalize a region's reduction burden, the ARB needs highly capable models to validly assess monetary and non-monetary costs associated with policy implementation.

To adopt regional targets before this statutory deadline, the ARB must utilize a preliminary and underdeveloped methodology to evaluate each region's reduction capabilities. These methods are based on a limited sample of empirical studies from different regions with varying local conditions. Limited information exists on policy sensitivity to local or regional conditions.

Current models have limited capability of adapting information on empirical policy studies to local conditions. Regions will continue to improve model accuracy and validity up to the point in the RTP process when the ARB must comment on the model. Setting targets by the statutory deadline in advance of the RTP process compromises some level of model accuracy and validity in selecting "ambitious, achievable" and equitable targets for regions.

The ARB will face difficulty in evaluating SCS and APS compliance

When an MPO begins its regional transportation planning process, the ARB must comment on the methodology the MPO will use to calculate the GHG impacts of its actions. The ARB must do this prior to the MPO selecting the SCS/APS implementation policies it plans to choose and forecast resulting GHG emissions. For MPOs which plan to use a model-based approach to calculate GHG emissions, the ARB must evaluate the model. Evaluating the capabilities of the model prior to knowing which individual policies and which group of policies requires that the ARB test the accuracy of the model under various policy scenarios, regardless of whether or not the scenario may be adopted. This places a large administrative burden on the ARB.

Some small MPOs will use the Best Management Practices tool as their first round methodology. The ARB will develop the Best Management Practice tool to capture the effects of various implementation measures, implemented individually or in a group. The RTAC recommended that the tool only include policies for which studies or travel models exist to measure their effects, and that the magnitude of the effects be based on these sources (Regional Targets Advisory Committee 2009, 21). Having developed the tool, the ARB will be familiar with its capabilities and should be able to approve the tool without difficulty.

One challenge in implementing the measure has been deciding how to attribute emissions for trips that cross regional boundaries. Ensuring that a regional attribution protocol assigns emissions in an accurate and equitable manner while reducing leakage, or increases in emissions in other regions, is essential to the long-term viability of regional GHG reduction programs.

The SB 375 Regional Targets Advisory Committee sought to attribute trips between or through California's regions based on a region's "ability to affect emissions from these trips through land use and transportation strategies" (Regional Targets Advisory Committee 2009). Specifically, the Committee recommended that trips between regions with shared boundaries be split equally between the regions. The ability of an attribution protocol to accurately and relevantly attribute emission becomes increasingly important as the proportion of trips between areas increases at more precise geographic levels. In some cases, an equal split may not accurately account for each area's ability to influence emissions from the trip. The state government, with funding for high speed and conventional rail programs, may have more strategies at its disposal to address emissions from trips which cross through multiple regions. Relevant attribution is necessary for cities and sub-regions to evaluate the performance of their GHG emissions management programs.

Part I Conclusion

While legal success with SB 375 is determined ex-ante, the failure of policies to succeed or of a region to meet its GHG targets could call into question the ARB's ability to evaluate SCS plans after 2020. In order to improve the ARB's ability to evaluate the GHG reduction effects of SCS plans, the state should pursue better models, empirical evaluation, and data to feed models and evaluation.

Part II – Removing barriers to successful SB 375 implementation

About this Part

Part II recommends data, methods, and investment needed to eliminate barriers to successful SB 375 implementation and accurate, valid measurement of GHG emissions from transportation .

Barriers to Successful SB 375 Implementation

The primary barrier to successful SB 375 implementation is the lack of accurate and valid forecasting and measurement of GHG emissions from transportation. Accurate and valid emissions modeling plays a key role in successful SB 375 target-setting, SCS development, SCS compliance evaluation, and successful achievement of a regional target.

Even in the absence of an SB 375-type policy, accurate forecasting is essential in evaluating the cost-effectiveness of new transportation policies and infrastructure. Financial underwriting of public-private partnerships to build new road and transit infrastructure will require that models have the ability to forecast aggregate price response effects of new policies. Cost-effectiveness evaluation will be an important part of programs that make project funding based on GHG reduction potential. The importance of cost effectiveness evaluations for transportation GHG reduction strategies will increase under a cap and trade system that includes transportation fuels. In such a cap and trade system, any policy or project which reduces transportation GHG emissions will produce an economic rather than environmental benefit. As the GHG cap is set independent of the project, the policy or project will not affect the amount of GHGs emitted within the cap and trade system[2]. The policy or project will serve to reduce demand, and prices, for allowances.

A second barrier to successful SB 375 implementation is that several California MPO's land use and travel demand models are not sensitive to policies regions might enact to achieve compliance with regional targets. While those who research and develop models have developed prototypes with advanced capabilities, deployment lags considerably behind development. The deployment of new, more capable models to new regions is currently expensive and time intensive. An increase in investment in models and empirical evaluation to support SB 375 implementation will speed the pace of innovation and development of new features, which could further fragment relative model capabilities unless deployment lags are reduced.

An additional barrier to SB 375 implementation is that insufficient information exists about the co-benefits of local and regional policies which may be implemented in SCS and APS plans. Local and regional decision-makers will seek to maximize non-GHG related co-benefits when selecting SCS and APS policies. Currently, models are not capable of forecasting changes to many factors other than future infrastructure needs, traffic congestion, and vehicle emissions. Factors which may influence policy adoption include:

- changes to infrastructure and maintenance costs (associated with compact growth),
- public health impacts (associated with changes in walking and biking),
- private transportation expenditures (vehicle operation and capital expenditures),
- building energy savings (associated with attached housing),
- localized exposure to fuel price volatility (transportation costs as a function of income, mode choice, and parcel accessibility),
- transportation network vulnerability to sea level rise (from climate and hydrological models),
- and water use reductions (for dense attached development).

[2] Unless allowances are acquired and retired because of the project.

Additional co-benefits are listed on page 42 of the RTAC Report. Improved models should seek to incorporate these and other co-benefits as model outputs in order to present decision makers with a more complete understanding of relevant information.

A fourth barrier to successful SB 375 implementation is that regional models are not relevant to local emissions managers. Cities and counties aim to create community GHG emissions inventories to serve as a baseline for emissions management. These jurisdictions will aim to use results from a regional transportation emissions model to conduct their inventories. While a variety of model implementations will be used for a variety of cases, in order to produce consistent results, the core engines of models should be similar between use cases, especially between geographic scales. Ideally, the sum of transportation GHG emissions from all city and subregional government inventories would equal total regional GHG emissions produced using regional modeling and measurement methods.

A fifth and final barrier to successful SB 375 implementation is establishing relevant GHG attribution protocols for trips which cross jurisdictional boundaries. One goal of attribution has been to assign responsibility for emissions based on a jurisdiction's ability to affect emissions. Because of the effects of trips between areas and the influence of policies at all levels of government, geographic based attribution fails to distinguish between the set of emissions an area can control or influence and those emissions within boundaries. An additional goal has been to reduce opportunity for emissions leakage, or spillover into other regions.

Recommendations to ARB for Target-setting & Rulemaking

Recommendation #1: Consider effect of regional growth rate on ability to utilize land use strategies when establishing targets

SB 375 requires the ARB set regional GHG reduction targets for 2020 and 2035 by September 30, 2010. The RTAC recommended that emission targets be set on a percent per-capita basis, based on 2005 emissions levels. One concern with such a baseline is that, while it is sensitive to population change, is not sensitive to the *rate* of population change. Faster growing regions will be better able to use land use strategies to meet their regional GHG reduction goals.

The following hypothetical situation describes two regions, A and B, which expect different rates of population growth but similar SB 375 targets expressed as a per capita reduction. While both regions must reduce per capita transportation GHG by 5%, they have different per capita GHG requirements for new residents. Region B, which has a high growth rate (10%) may be able to fulfill its reduction targets with land use strategies alone – by achieving average transportation emissions of 8.1 MT CO_2-e per capita for all new growth. With a marginal per capita GHG target of -4.5 MT CO_2-e per capita, Region A will not be able to meet its target with land use strategies alone.

Figure 1 - Hypothetical Difference in Growth Rates and New Resident Emissions

	Region A	Region B
2012 Population	1,000,000	800,000
Per Capita CO2-e	15.0	18.0
Region-wide CO2-e (MT)	15,000,000	14,400,000
Per Capita GHG Reduction Goal	5%	5%
2017 Population Projections	1,040,000	880,000
Population Growth	40,000	80,000
Population Growth Rate	4.0%	10.0%
New Region-wide Per Capita CO2-e	14.3	17.1
Region-wide CO2-e (MT)	14,820,000	15,048,000
Per Capita CO2-e for New Residents	-4.5	8.1

The RTAC report acknowledges that differences in regional growth rates affects the results a region may achieve with land use and transportation strategies. However, only if the rate of population change is considered will a per capita reduction metric ensure "that both fast and slow growth regions take reasonable advantage of any established transit systems and infill opportunity sites to reduce their average regional GHG emissions" (Regional Targets Advisory Committee 2009, 24).

Recommendation #2: SB 375 has a bias towards strategies with early maturities. The ARB should recognize this and either adjust targets and compliance methods or effectively communicate the value of land use strategies to MPOs

The legislative intent of SB 375 is clear: a changes in land use patterns and transportation policy are necessary to achieve the GHG reduction goals of AB 32. In order to achieve these reductions, MPOs must pursue strategies which meet targets for GHG reductions from transportation in 2020 and 2035. This structure favors the implementation of transportation strategies over land use strategies for two reasons. First, land use strategies have complimentary effects to transit and pricing strategies, and in isolation are less effective. Second, land use strategies have a longer maturity term than transit and pricing strategies. The potential GHG reduction effects of a change in regional land use patterns will not be fully realized until well after 2035. While the implementation of land use strategies may have limited GHG reduction effects prior to 2020 or 2035, an MPO may seek to implement land use strategies for their non-GHG benefits.

Table 1 below shows the percentage of projected 2050 GHG reductions achieved by various strategies in 2020 and 2030. The *Moving Cooler* report forecasts the nationwide GHG reduction effects of various transportation and land use strategies at three deployment levels[3]. At all levels of deployment, pricing strategies reach their 2050 level of effectiveness by 2030. Land use strategies, however, achieve less than half of their 2050 GHG reduction levels by 2030.

Table 1 - Percentage of 2050 GHG Reduction Potential for Various Strategies in 2020 and 2030

PERCENTAGE OF 2050 REDUCTION BY YEAR AND DEPLOYMENT LEVEL						
	Expanded Current		Aggressive		Maximum	
Strategy	2020	2030	2020	2030	2020	2030
Pricing						
Congestion Pricing	28%	100%	31%	100%	46%	110%
PAYD Insurance	105%	100%	89%	107%	95%	107%
VMT fee	114%	114%	114%	109%	112%	108%
Carbon Pricing (VMT)	110%	100%	114%	111%	103%	105%
Carbon Pricing (fuel economy)	63%	97%	66%	97%	73%	100%
Land Use						
Combined Land Use	10%	30%	16%	49%	16%	52%
Combined Pedestrian	100%	100%	100%	100%	100%	117%
Transit						
Transit Frequency	50%	100%	33%	67%	22%	44%
Urban Transit Expansion	29%	57%	33%	58%	31%	54%
Commute Strategy						
Employer-Based Strategy	100%	100%	115%	108%	113%	110%
Regulatory Measures						
Urban Parking Restrictions	7%	14%	8%	31%	17%	50%
Speed Limit Reduction	29%	107%	56%	106%	71%	106%
System Management						
Eco-Driving	22%	50%	28%	54%	58%	77%

KEY
< 33%
33% to 66%
> 66%

Based on (Cambridge Systematics 2009, 44-45)

Land use strategies are complementary to pricing and transit strategies: they allow urban and regional form to adapt to a new regime of transportation pricing and travel mode options. Land use strategies that reduce demand for distance traveled and promote the use of alternative modes not subject to carbon pricing will mitigate the impact of pricing on quality of life and social equity.

[3] For scoping purposes: the carbon pricing represents a new fuel tax of $0.40 per gallon at the expanded current practice level, $0.82 per gallon at the aggressive level, and $2.71 per gallon at the maximum level.

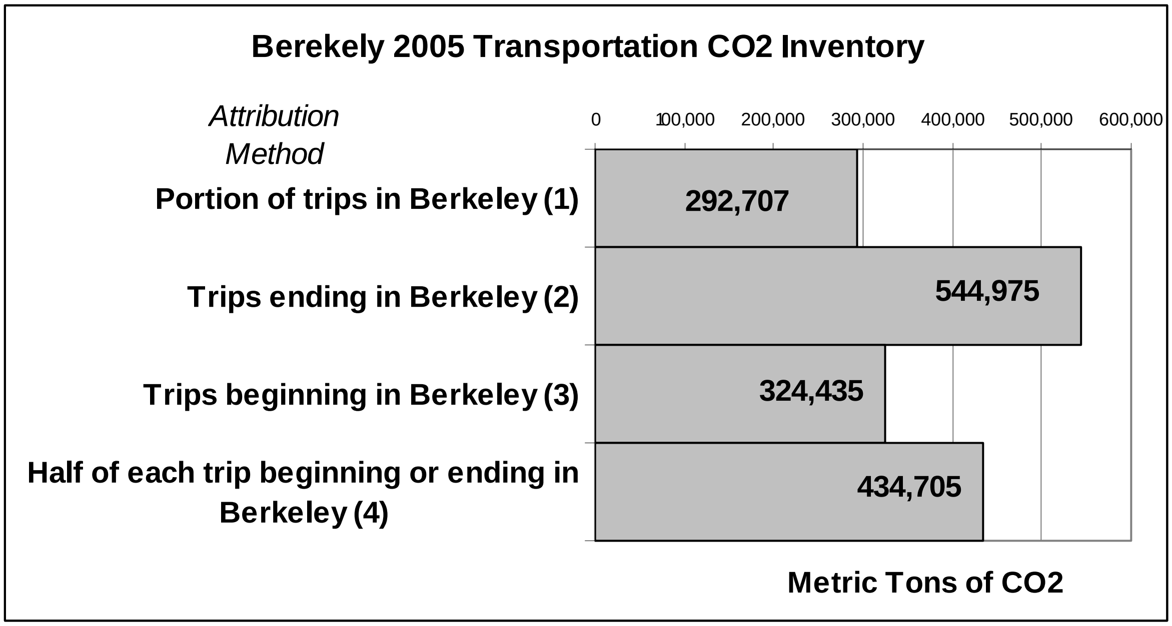
There may be limited cause for concern about SB 375's favor towards pricing strategies, as MPOs might find available land use strategies (infill development, strategic density increases, and the mixing of land uses) politically preferable to potentially available pricing strategies (congestion pricing, VMT fees, and carbon-linked gasoline fees). Nevertheless, the ARB should be aware of SB 375's systematic bias for strategies with early maturities and work with MPOs to communicate the benefits of land use strategies, or allow adjustments the value for such strategies versus their actual 2020 and 2035 forecasts.

Recommendation #3: Attribute emissions to jurisdictions based on their ability to affect those emissions

The Regional Targets Advisory Committee (2009, 26) recommended "an MPO's ability to affect emissions from these trips through land use and transportation strategies should be a key factor in determining how trip emissions are apportioned among MPOs." Currently, researchers do not have sufficient confidence in models to assign responsibility for emissions based on model and evaluation results. However, improved modeling and evaluation could enable measurement of a jurisdiction's ability to affect emissions.

Using existing data, GHG emissions from transportation can be attributed to jurisdictions in four ways. These attribution protocols include: (1) allocating emissions from the portion of vehicle activity within a jurisdiction or geographic area, (2) allocating emissions from trips which end in a jurisdiction, (3) allocating emissions from trips which begin in a jurisdiction, or (4) some combination of the latter two. The results of these attribution protocols can vary widely. Figure 2 below shows the difference in totals for each of these attribution methods for Berkeley's 2005 transportation CO_2 inventory

Figure 2 - Berkeley , CA vehicle CO_2 under 4 attribution protocols



Source: (Ganson 2008)

The attribution methods used in Berkeley, while accounting for trans-boundary travel, do not account for the effects of policies and programs enacted by the state or adjacent local governments. The transportation system has multiple jurisdictional tiers, and policies implemented by states jurisdictions can affect emissions in regions and cities. For instance, a state government may implement a policy that increases the cost of vehicle travel, and consequently reduce trip-making and GHG emissions in regions and cities. Additionally, regions or cities can implement policies that affect emissions in contiguous or nearby regions or cities. For instance, improvements in bicycle infrastructure in one jurisdiction may reduce vehicle travel in another jurisdiction. See **Error! Reference source not found.** in Part I for an example of various policies grouped by the implementing jurisdiction level. Future attribution protocols may seek to incorporate inter-jurisdictional policy effects in attributing emissions to jurisdictions.

Such an attribution protocol would be relevant to municipal GHG management – localities could evaluate GHG emissions performance against emissions that they can control.

In the long run, an attribution protocol based on a jurisdiction's ability to affect emissions could be used in compliance, incentive programs, and target-setting .One reason the state may choose to use the set of controllable emissions as a basis for GHG reduction target-setting is to avoid legal and political ambiguity that may result when a state policy jurisdiction's policy fails to meet forecasts. For instance, if a statewide VMT fee or pay-as-you drive insurance results in a lower than forecast VMT reduction that is and regions with a GHG reduction target are held accountable for emissions within their geography, a region may fail to meet its GHG emissions reduction target as a result of factors which it does not control.

Choosing an emissions attribution protocol for regional target-setting and incentive programs is a political decision. High quality information about a jurisdiction's ability to affect emissions can enable policymakers to choose an attribution protocol that is equitable and accurate.

Recommendations to the California Transportation Commission for model & data improvements

While the ARB will implement SB 375, the California Transportation Commission (CTC) oversees guidelines for models and data used in RTPs and travel demand models. In implementing SB 375, the legislature found

> (g) current planning models and analytical techniques used for making transportation infrastructure decisions and for air quality planning should be able to assess the effects of policy choices, such as residential development patterns, expanded transit service and accessibility, the walkability of communities, and the use of economic incentives and disincentives.
>
> (California Sen. Bill 375 § 1 (g), 2008).

As outlined in Part I, current models do not meet this criteria. To develop this capability, the CTC should oversee an expansive, long-term model and data improvement program. The required initiatives of this program are presented in the following section.

Recommendation #4: The California Transportation Commission should form a task force to create guidelines for state-funded models that promote process-driven model engines and data interoperability to reduce model assimilation time and costs

The policy motivation for transportation & land use planning is changing from a forecast of road-building requirements to the development of a complete, multimodal transportation infrastructure and complimentary policies and programs to affect travel behavior. Models used in transportation planning are responding to this new motivation. With an expansion of modeling needs and computing power, models are becoming micro-simulations of real life. This changing field has new data and methodological requirements. Advanced models have a thirst for real world data to calibrate and animate the regression functions that drive their results.

About modeling

Modeling is the art of using currently available data and statistical methods to predict future outcomes, including GHG emissions from transportation. Models used to forecast GHG emissions from transportation are comprised of several components.

The first is the land use model, which describes zone or parcel[4] characteristics such as density, use, accessibility, demographics, and economics. Some of the most advanced land use models in

[4] Historically, the scale of geographic analysis for models has been Traffic Analysis Zones which encompass several blocks. As better data becomes available, the scale of geographic analysis is becoming more precise, and block or parcel level data is becoming more common

California are based on the PECAS[5] model. PECAS is a general equilibrium model which simulates spatial economic systems based on assumptions about economic trends, the current state and planned state of transportation infrastructure, and transportation and land use policies to forecast the future locations of and economic relationships among firms and households.

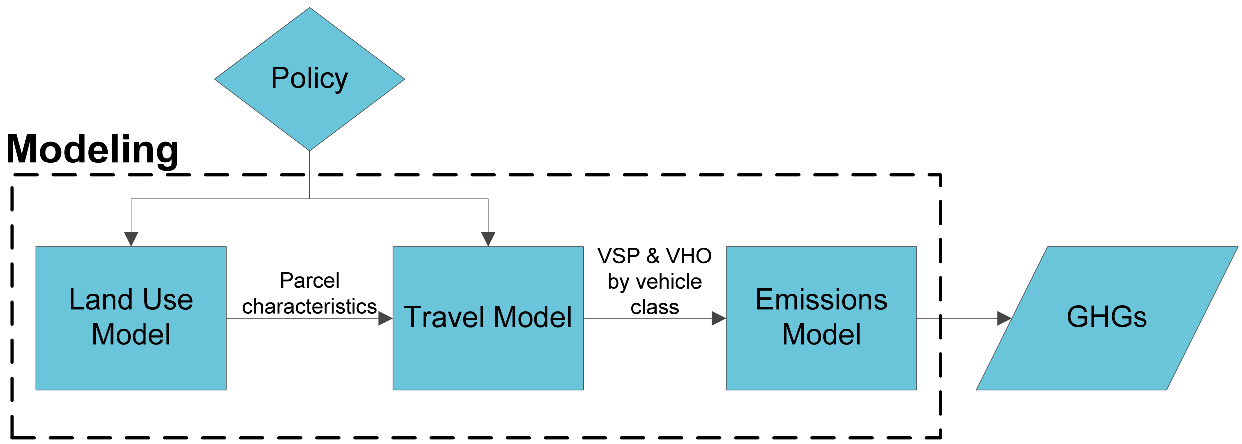
The second model is the travel model. Activity-based travel models are emerging as the preferred approach to predict daily travel itineraries and mode choices for individuals. These models create a space-time path through which individuals travel during the day. Activity based models integrate with a network assignment tool to predict routings, and interactions between vehicles. This travel activity data can be used to predict vehicle speeds, congestion, and vehicle miles traveled.

Two classes of models are used to produce emissions estimates from travel activity data. The models differ based on their statistical approach to describing the relationship between travel activity and vehicle emissions. The U.S. EPA MOBILE[6] and California ARB EMFAC models use vehicle speeds to estimate emissions. The EPA MOVES emissions model uses vehicle engine load to estimate calculate emissions. The authors recommend use of a modal emissions model such as MOVES2010 in recommendation #7.

[5] Production, Exchange, and Consumption Allocation System

[6] MOVES2010 has replaced MOBILE for use in air quality conformity analysis.

Figure 3 - Land use and transportation modeling to forecast GHG emissions (simplified)



The California Transportation Commission (CTC) should convene a task force of model developers and users to develop a plan to guide the state's long-term investment and guidelines for models and related research. The mission of this task force would be to develop longer-range guidelines than currently created by CTC Modeling Subcommittee for RTP Guidelines, but the task force may contain many of the same members. The long-term plan should address:

1. The consistency and interoperability of models between areas and scales
    a. Land Use, Travel, & Emissions models are used at a variety of geographic scales (intersection/point, project, neighborhood, city, county, region, state). As boundaries between these scales may be at times ambiguous, the same process-driven model engines should be utilized at each scale to promote consistency. A goal should be that the sum of sub-regional model results is equal to regional models results.
    b. While the results of a project-level model will be influenced by regional travel activity, it is not practical to conduct a regional model run to evaluate one project or neighborhood-level policy. The results of a regional model should be available

and useable in localized models. This is likely to require that an expanded array of outputs be passed between models.

   c. Travel models should integrate well with emissions models at all geographic scales. U.S. EPA's MOVES2010 functions at all scales.

2. Interoperability of Data and Models

   a. Establish standards for all model interfaces to enhance interoperability of model engines. Enhance a model's ability to pass data between engines. For instance, micro-simulations used to forecast congestion can be used to produce vehicle specific power and vehicle hours operating for emissions estimates. This data can currently become lost between model engines.

   b. Establish standards for current and future model engine outputs. New models can be developed that use these outputs. For example, a model which estimates co-benefits could be developed to interface with current and future output data.

   c. Determine what data is needed to calibrate and animate data, and if the collection and formatting of this data be standardized between regions to facilitate model assimilation

3. Process to manage model improvements and deployment

   a. Establish a system for community-based model contributions and distribution of official updates.

   b. Consider the potential of a adopting a common programming, scripting language, and database system to enhance interoperability between model engines and cross-functional developer contributions.

The above concepts are not new to the modeling community. The established Urbansim and TMIP model development frameworks used similar principles for over a decade. However these efforts have been limited to a subsection of land use, travel, and emissions modeling. A move towards modeling programs and policies over new infrastructure and use of emissions outputs in incentive programs necessitates a reevaluation of how all model engines can better integrate to produce more accurate results for a variety of outputs.

Recommendation #5: Invest in empirical evaluation programs and develop a standardized empirical evaluation framework

Empirical evaluation is the cornerstone of effective SB 375 implementation. Just as sensitive, accurate models are essential to selecting policies and demonstrating SB 375 compliance, evaluation research is essential to developing sensitive, accurate models. Current models are not able to forecast the effects of many new policies or programs a region may seek to implement. Models require data from empirical studies on how travel behavior might respond to the policy or program. Existing transportation data is cross-sectional and spatially and temporally sparse and generally not considered robust (Boarnet 2010). Policy evaluators currently lack sufficient observations to make valid statistical inferences for specific areas, or enough observations over time to measure how a policy changes individual behavior. Producing the additional observations, panel data, will require cooperation among researchers, funders, and users of models and data.

Representatives from various state agencies (including Caltrans, CTC, ARB, and agency members of the Strategic Growth Council), MPOs, and the University of California Institute of Transportation Studies should develop a plan for empirical evaluation and increase funding in this area. In the near term, policy evaluation funding should be increased in order to evaluate SB 375 implementation programs and gain experience with program and project evaluation in the context of CEQA exemptions and regional GHG targets. Concurrently, the groups should establish a working group of policy evaluators to create a standardized, updateable framework for policy evaluation and make recommendations on local and state-level data needed for implementation (see Recommendation #6).

With SB 375, regions seek to implement policies, programs, and develop infrastructure as part of a Sustainable Communities Strategy that complies with regional GHG reduction targets. At the same time, regional models are not fully capable of forecasting the effects of the various components of a Sustainable Communities Strategy. This conundrum presents both a challenge and an opportunity. While not all regions will be able to accurately and validly forecast policy effectiveness during the first round of SB 375 implementation, all regions will implement policies and programs. By evaluating these policies and programs, researchers will produce valuable information about policy sensitivities, alone and in groups, that will enhance a region's ability to select effective policies and demonstrate compliance with subsequent Sustainable Communities Strategies. (The evaluation of region-wide performance against a GHG target is discussed in Recommendation #9).

Process for Scientific Evaluation of Transportation and Land Use Policies

Researchers conducting transportation and land use policy evaluation are interested in how a policy/action affects individual travel behavior, for example how it causes an individual to deter a trip, chooses make a trip using a different transport mode, or reduce the distance traveled. To develop and evaluate a model's ability to forecast the results of a specific action[7], or groups of actions implemented concurrently, researchers must gain confidence around the potential effects

[7] Here I use the term action to refer to a change in transportation or land use policy or a change in transportation infrastructure

of an action, and how these effects depend on local conditions. This requires that researchers design and conduct experiments. To evaluate how an action affects travel behavior, it is necessary to compare the effects of an action with the effects of the absence of an action. Controlled experimentation, in which the researcher can create identical areas which differ only in the presence or absence of the action the experimenter wishes to evaluate, is not practical in the transportation sector.

To evaluate the effects of various actions on travel behavior, researchers must use a form of natural experimentation. Natural experimentation includes before and after studies and studies that compare areas. There are several challenges to evaluating the effects of a specific action.

The first challenge is that collecting observations for an area both before and after an action can be difficult. In many cases, evaluation may be an afterthought, or there may not be sufficient time to collect observations before an action is implemented.

The second is that local actions are often implemented concurrently, and it is difficult to isolate the effects of a given action on travel activity within a geographic area when multiple new and existing actions act in concert to affect travel activity. Even if evaluators could isolate the effects of a single action, the experiment would still lack a control[8] against which observed effects could be evaluated. For instance, an area where actions *A*, *B*, and *C* have been implemented could be compared with a similar area where actions *B*, *C*, and *D* are present to extrapolate the effects of action *A*. A sufficient sample of areas where A is and isn't occurring would be required in order to make statistically valid observations about the effects of action *A*.

[8] a comparison of the same area without the action

Many factors affect travel behavior in addition to the policy or program actions being studied. Researchers must control for differences in urban form, incomes, pre-existing modal split, and other factors before, during, and after the study period. A large sample size is required to capture enough observations of actions and local variations to overcome the statistical noise produced by this method. Through this method, it is also possible to estimate co-variance, or synergies, among groups of actions.

Local conditions which vary between areas and times will influence the effectiveness of an action. The interaction between transportation and land use is a complex system, and the implementation of a primary action may induce second order[9] effects that change local conditions, and in turn, alter the first-order effectiveness of the primary action[10]. For instance, increasing the price of parking in a central business district may shift more trips to transit. The transit agency may meet this demand increase with an increase service frequency, which may induce additional transit trips. Thus, it is necessary to measure changes in these local conditions through time, and evaluate how changes could be a result of the primary action.

The experimental challenges described above require a new of investment and methods in the transportation empirical evaluation. First, program evaluators need panel data[11] from multiple evaluation cases to enhance the robustness of results in any one evaluation case. To develop this panel data the program evaluation community needs to first take steps to standardize the experimental framework, so the data produced by evaluators is universally useful to other evaluators. With a standardized experimental framework will come the need for common input

---

[9] Second order effects are caused by primary effects

[10] Also known as feedback effects

[11] Multi-dimensional data from studies of individual and/or aggregate response to multiple policy implementations with observations for multiple time periods for each observations

data requirements, and collection of this data (see recommendation #6). Input data will describe the area being studied, the policy or policies being implemented in that area, the observed results in terms of individual behavior expressed as travel activity, and associated emissions changes. The next step is to apply robust statistical models capable of disentangling policy effects from other observable trends in the data.

Then policy and program evaluation models that process input data to create data on policy sensitivity, including but not limited to:

- Mean, central tendencies, and variance (distribution) of the expected GHG reduction impacts of policy A.
- Relationship of ΔGHG emissions attributable to Policy A to variables external to the policy, such as local incomes, urban form, fuel prices, area rents, local economic activity.
- Relationship of ΔGHG emissions attributable to Policy A to several intensive and extensive policy variables, (such as level of implementation, geographic area effected, level of pricing, % of population effected by policy, etc.)
- Covariance of ΔGHG emissions attributable to Policy A to ΔGHG emissions attributable to Policy B, and groups of policies to other groups of policies
- Note: ΔGHG emissions is one of many performance outcomes that can be measured and modeled. Empirical evaluation studies can produce information related to the many co-benefits of these actions.

Figure 4 - Evaluators are interested in the following equation

$$Action_A \rightarrow \sum \Delta\ Individual\ Travel\ Behavior_\alpha \rightarrow \begin{cases} \Delta Vehicle\ Specific\ Power_{(x,y)} \\ \Delta Vehicle\ Operating\ Hours_{(x,y)} \end{cases} \xrightarrow{yields} \Delta GHG_{x,y}$$

As the standardized framework, input data requirements, and policy evaluation model mature, researchers can then take steps to automate the empirical evaluation. Creating and implementing the standardized framework is the first step in automating the process. The next step is automating the collection and processing of data required for empirical evaluation. Automation will not eliminate the need for empirical evaluation research. Researchers will continue to conduct emerging approaches to empirical evaluation; using new methodologies, new data, and attempting to evaluate new co-effects in order improve insight into urban and regional dynamics surrounding transportation and land use.

Comprehensive policy and program evaluation will become more accessible as input data collection and modeling are automated. As robust evaluation becomes less resource intensive, the state and cities can direct staff and those seeking development project approval to apply the standardized evaluation framework to new projects, programs, and policies. Greater accessibility of the empirical evaluation framework will increase the number of available observations and strengthen the results.

The standardized framework plan should leverage current UC Davis efforts to develop a standardized protocol that local governments can use to do evaluation of their own policies. This protocol will be "something rigorous but easy and affordable to apply" (Handy 2010). In selecting policies, evaluators should initially focus on those which are easy to evaluate and which appear to be the most effective (Boarnet 2010).

Recommendation #6: Create a statewide office to leverage economies of scale in collecting and preparing input data for use in multiple sectors

Effective land use, transportation, and emissions modeling and policy or program evaluation begins with the collection and processing of raw data. In evaluating transportation and land use policies, data is used to describe land uses, travel behavior, and policies being implemented. While some of this data is being collected, it is not available at the spatial and temporal resolution required for robust policy evaluation (Boarnet 2010). Effective policy and program evaluation will require substantial additional data. At the same time, new data collection technologies have allowed for the collection of higher resolution, more accurate data at substantially lower costs. This is true both for data that describes the movement of people and vehicles, and data that describes local demographics, economics, land uses, and transportation infrastructure.

The state should establish a statewide bureau or office on integrated data solutions to collect, process, and analyze data used in decision-making at the state, local, and regional level. This office can leverage economies of scale in creating statewide datasets and processing data and facilitate cross-sector data sharing. Data collection and processing has been a barrier to effective evaluation by researchers and governments. By making data and analysis more usable, local staff and policymakers can engage in evidence-based management and more informed decision-making.

The office's work should not be confined to the development of new data sources. Existing data currently used in one sector can be repackaged and disseminated for use in multiple sectors. With an increased interest in modeling the co-benefits of policy decisions, the difference in data needs between policy sectors is breaking down. Infrastructure costs and water usage associated with greenfield and infill development patterns were once irrelevant to transportation modeling. Now, decision makers seek this information when evaluating macro and micro level land use policy options.

The office should assemble an advisory board comprised of data users from state government (not limited to transportation, including Department of Housing and Community Development, CalEPA, and others), MPOs, local governments, the Strategic Growth Council's Data Subcommittee, members of the long-term model improvement taskforce (from Recommendation #4), and the group tasked with developing a standardized policy evaluation framework (see Recommendation #5). The advisory board would make recommendations on long-term data needs, priorities for data collection and processing, and standards for public data in California.

Table 2 - Data to be collected and processed for the transportation and land use may include:

Data which describe land	o Parcel zoning information from local general plans and variances, current use o Census block group demographics o Parcel or census block group or tract economics , such as parcel value from county assessor, income levels of census block group, sales tax collected at parcel
Data which describe travel activity (vehicle based) and travel behavior (individual based)	o Roadway sensor data (PEMS), o Regional travel survey responses o In vehicle or personal device GPS data logs from empirical studies and consumer products
Information about policies being implemented	o How policies affect terminal costs, vehicle operations costs, mode choice, etc.

In many cases, the data described is currently collected and available at the local level. However, it is not typically readily available to evaluators and those in neighboring areas. Additionally, the data structure and quality may be inconsistent between areas and create difficulties for evaluation projects that span multiple local areas. The office could establish voluntary standards for local data quality and preparation that facilitate regional and statewide evaluation research.

In addition to improving the quality and coordination of existing data across sectors, the state office should work to collect data from new sources. Perhaps the most promising data source to measuring and modeling GHG emissions in the transportation sector is GPS data that captures vehicle movements and personal travel activity. There are two uses for this location data. The first use is anonymous, fine resolution data on vehicle activity that can be used in creating vehicle specific power profiles for specific roadway links to be used in emissions modeling. Such data can be used for a number of purposes, including measuring the effects of traffic congestion on vehicle GHG emissions. GPS is already being collected in some areas from trucks, taxis, and government vehicles. The second use of location-based data requires data at a more coarse geographic and time resolution to track individual travel activity. For researchers to evaluate how different people and households respond to transportation policies, this data would need to be collected for each individual in a household and connected to their demographic information.

The cost of collecting and reporting real-time GPS data has fallen substantially in the past decade. California's Statewide Household Travel Survey in 2000 had fewer than 2% of participants successfully use a GPS device in conjunction with the travel diary (California Department of Transportation 2002). Now, many vehicles have on-board GPS systems and many mobile devices have GPS capabilities. The challenge in utilizing GPS data in travel surveys is no longer collecting the location data. The challenge is now managing the abundance of potential data: prioritizing what data to collect, developing travel survey applications for mobile devices, negotiating data licensing agreements, and processing the data for use in travel modeling and policy evaluation.

While transportation and land use sector lacks sufficient data for robust policy evaluation, the need for additional geo-referenced data is not unique to this sector. The state office would facilitate cross-sectoral data usage by leveraging economies of scale in providing data to multiple users.

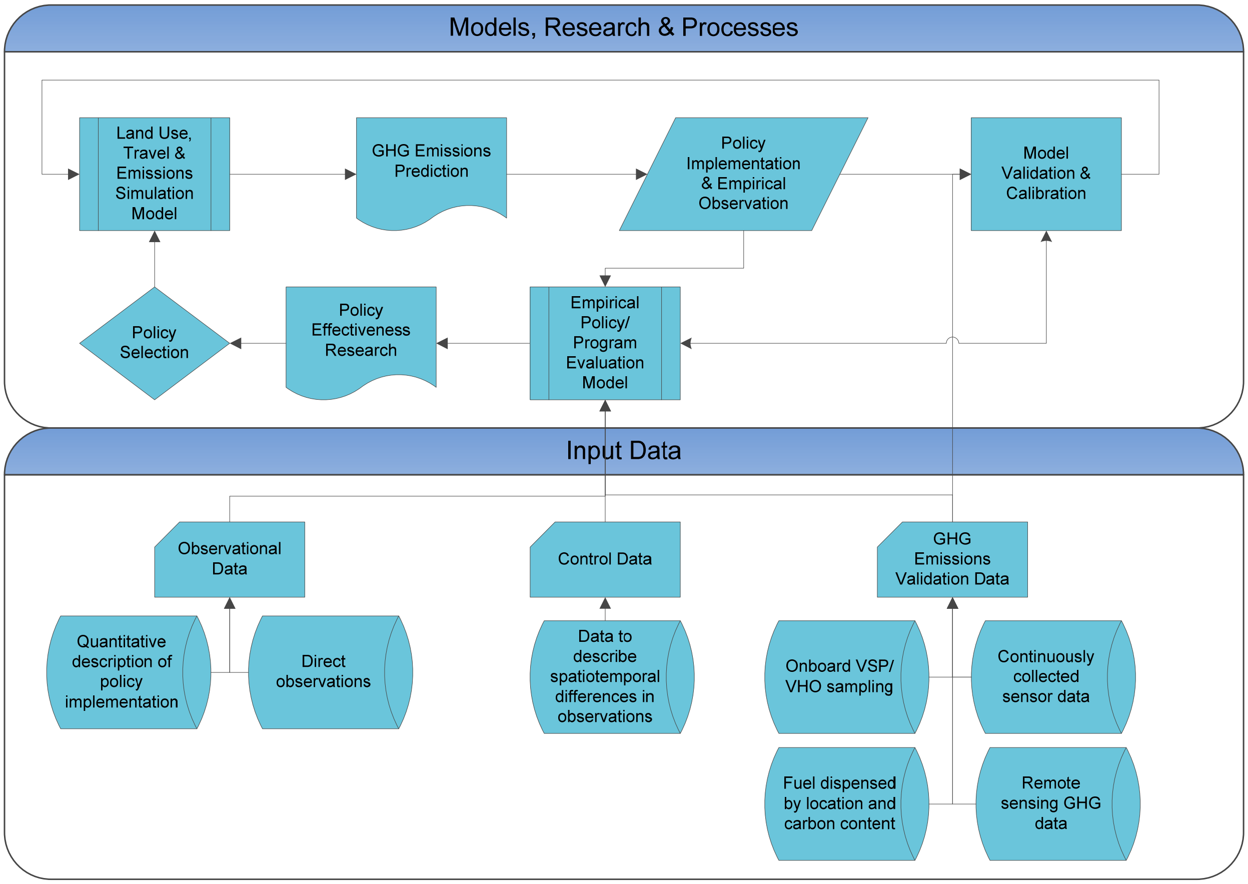
Sidebar: Example of cross-sectoral data uses:

Various data users in the state currently use LiDAR[12] data. Such data can be processed for use in a number of applications, including describing tree cover. If tree cover data is analyzed with the transportation network and travel survey data, it could allow for evaluation of how trees and shading impact biking and walking trips. Utilities and state boards can use the data to analyze the impact of tree coverage on water and energy usage. The data could also be used to estimate the carbon sequestration capabilities of trees and vegetation. While any one of these users may not devote resources to collect and process the data, the sum of benefits to all users may exceed the costs for a single entity to collect and process such data.

In addition to driving more accurate and valid model results and supporting widespread policy evaluation, improved data will reduce model deployment costs. With high quality, standardized data MPOs will be able to calibrate and adapt model tools to their region without developing interfaces between proprietary regional data and models. This will reduce deployment delays and work towards ensuring that every region has a highly capable modeling system that is adapted to their unique conditions.

[12] Light Detection and Ranging

Figure 5 - Relationship between models, empirical evaluation, and data



Recommendation #7: The ARB should transition from using the EMFAC emissions model to a modal emissions model such as U.S. EPA's MOVES2010

Modal emissions models, such as the U.S. EPA's MOVES2010 model, have three advantages over existing models: modal models can be more accurate, modal models allow for space/time explicit emissions estimation, and modal models allow for emissions analysis at a variety of geographic scales. The MOVES model uses a different architecture to calculate vehicle emissions than previous emissions models based on vehicle miles traveled (VMT) and average vehicle speed. MOVES uses second-by-second vehicle specific power (VSP), which has been found to better correlate with emissions than average vehicle speed (Koupal, et al. 2002).

Researchers have found that modal emissions models, including MOVES, are better able to account for congestion, road grade, and other factors that can affect vehicle engine load but not average speed. Existing macro-level models do not capture the full impact of traffic-flow efficiency and its impact on fuel consumption (California Transportation Commission 2010, 54). Using a modal emissions model such as MOVES will allow policymakers to measure the GHG reduction effects of congestion reduction policies. Barth and Boriboonsomsin (2008) found that a microscale modal emissions model that is sensitive to second-by-second variations of fuel consumption and emissions is more appropriate for measuring emissions from congestion than regional emissions inventory models. Song, Eisnger and Niemeier (2009) write that, versus MOBILE and EMFAC, MOVES "should be more responsive to variations in traffic dynamics and roadway congestion levels." MOVES can account for road grade, which has a significant effect on fuel consumption (Fernández and Long 1995) (Park and Rakha 2006).

The MOVES architecture allows for emissions analyses that are space and time explicit, which enables their use at variety of geographic scales. The two expressions of vehicle activity that MOVES is based on, service hours operating and vehicle specific power, can be assigned to a specific geographic point. This allows the MOVES model engine to be used for a variety of geographic scales: from the intersection, to the project, to the region, to the state. Because of this flexibility of analysis scale, and incorporation of operating time and mode inputs, "MOVES is anticipated to be a superior analysis tool" than MOBILE and EMFAC" (Song, Eisinger and Niemeier 2009).

In transitioning to MOVES2010, the ARB and other users of emissions models should substitute appropriate local inputs on vehicle activity, vehicle mix, and emissions factors instead of the standardized national inputs provided with the MOVES2010 model (J. Koupal 2010).

Recommendations for the future of SB 375 implementation and evaluation

Recommendation #8– Use fuel sales and remote sensing to validate CO_2 emissions measurements

Two data sources not used as inputs to transportation and emissions models can be used as a check to validate model CO_2emissions forecasts and measurements. The first of these data sources is quantity of fuel used, readily available but not useful for measuring emissions at precise geographic scales. The second data source, remote sensing, is emerging and currently unavailable at any usable scale.

Vehicle CO_2 emissions are directly proportional to fuel used. Molecules in fuel are mostly composed of hydrogen and carbon atoms. When fuel is efficiently combusted in a vehicle engine, the each atom of carbon in gasoline combines with two atoms of oxygen to become CO_2. The CO_2 output produced by an emissions model for an area can be compared with fuel sales from the same area to validate the emission model data. There are limitations to this method, however. With smaller geographic areas and areas that are not contiguous with a travel shed, the proportion of entering or leaving an area after refueling can be high, making data on fuel dispensed only marginally useful at these geographic scales. A combination of vehicle activity data and more precise data on the location of fuel dispensed can be used to increase the usefulness of such data in validating CO_2 outputs from emissions measurements.

Sidebar: Current errors in travel activity modeling and fuel-based approaches

The State of California currently uses data on fuel dispensed to scale outputs from travel emissions model for purposes of the state's GHG inventory. Results from this data indicate difficulties in reconciling the two outputs. The median error between the two figures has between 1990 and 2004 was 3.8%, or roughly 5 MMT CO_2e (Matute 2010).

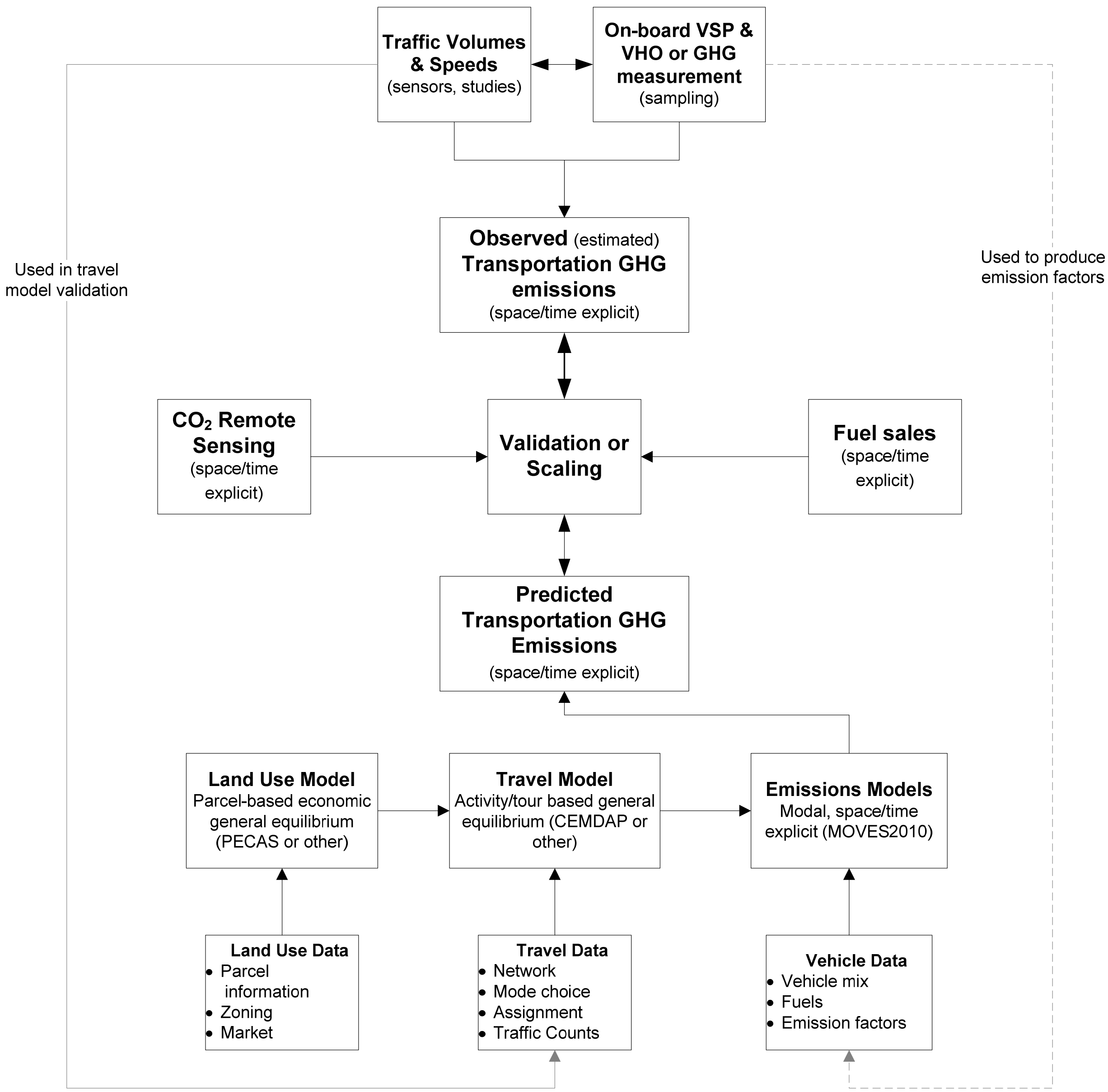
The second data source, remote sensing, is more complicated but could be used to validate results of emissions models at more precise geographic and time scales than fuel use data. Remote sensing exists in various applications, including satellite analysis of gas density and airborne and terrestrial measurements of CO_2 concentrations. These measurements must be reconciled with known information about emissions sources and atmospheric transport in order to produce meaningful inferences about GHG emissions sources and quantities.

The need to verify compliance with international GHG emissions reduction agreements is driving the development of remote sensing techniques. Researchers have years of experience using roadside remote sensing for criteria pollutants and CO, however using remote sensing to measure CH_4 and CO_2 emissions at the urban scale is an emerging approach. Early experience using measurements from aircraft in Indianapolis, IN suggest that, when combined with known data about emissions sources, the method is somewhat capable of distinguishing mobile source and stationary source emissions (Mays, et al. 2009).

Remotely sensed measurements could be useful in producing more accurate urban scale GHG emissions inventories for all sectors – including transportation. By comparing expected GHG concentrations with observed GHG concentrations, researchers could potentially validate and scale transportation emissions model results. Additionally, producing GHG emissions estimates at high space and time resolutions will assist in the development of accurate cross-sectoral urban scale emissions inventories. More precise information about emissions from mobile sources will allow researchers to deduce emissions measurements for sectors where direct measurement cannot be currently employed, such as fugitive emissions from landfills and natural gas pipelines and process emissions from wastewater treatment.

Remote sensing is years away from wide-scale deployment at the urban scale. Deploying this method at the urban scale will require models to output GHG emissions for precise grid areas or roadway links at higher time resolutions than currently produced. Those developing the next generation of travel models should seek to produce space and time explicit outputs whenever possible in order to maximize the potential usefulness of these models to cross-sector emissions measurements efforts, including remote sensing.

Figure 6 – Use of fuel and remote sensing data in validating GHG predictions and observations



Recommendation #9 : Policy evaluators should could control for exogenous factors in evaluating SB 375 target performance in 2020 (and 2035)

The success of SB 375 will be evaluated at several stages. The first stage is compliance: are regions able to demonstrate that their fiscally constrained SCS will allow them to meet GHG reduction targets in 2020 and 2035. Successful MPO compliance with SB 375 is contingent on the adoption of a SCS or APS that demonstrates the region will meet its GHG targets. The second stage is success in implementing a SCS: whether or not new transportation facilities were built, policies and programs were implemented, and local governments rezoned land uses in accordance with the SCS. The third stage is evaluating actual per capita emissions in 2020 and 2035 against regional reduction targets. The SB 375 bill contains no provisions for evaluation of targets versus actual emissions in 2020 or 2035, but that such evaluation will play a strong role in determining the success of SB 375 and the need for follow on legislation, and will serve as an assessment of the ARB's ability to approve an SCS that will allow a region to achieve its GHG goals.

A region could submit an approved SCS and implement all of the strategies outlined by the document, but fail to actually meet its GHG reduction target in 2020. Conversely, a region could fail to implement the measures of an approved SCS or APS and still meet its 2020 GHG reduction targets. There are two situations in which such scenarios could occur. The first is that models, given predicted assumptions about economic activity and fuel prices, fail to accurately predict the GHG reduction effects of implementation policies and programs. The second scenario is that is that factors beyond regional control, such as economic activity and fuel prices, affect regional GHG emissions and actual emissions in 2020 deviate from modeled forecasts of approved SCS plans. While an MPO-imposed carbon fee could allow an MPO to adjust fuel prices, the greater proportion of the total price will be set by market forces and state and federal taxes. Should an MPO get credit for emissions reductions that are attributable to an increase in the market price of fuel, or be penalized for emissions increases attributable to a lower than expected fuel price?

SB 375, though framed by regional GHG reduction targets, is primarily a planning exercise. In practice, future economic and fuel price variability doesn't matter – strategies will be committed to in advance of known information about changes in fuel price. Still, the policymaker and policy research communities should decide how to evaluate regional targets in the context of factors MPOs do not control. This requires controlling for a number of factors external to the MPO, including fuel price, economic activity, and unemployment levels. Additionally, policymakers and policy researchers should decide how to evaluate early annual reductions in GHG emissions the context of overall GHG concentrations. It is possible region may beat its 2020 targets but exceed its 2035 targets, all while releasing fewer total GHG emissions between 2010 and 2035 than if it had met its 2035 targets.

Also to be determined is how policymakers and researchers will evaluate SB 375 success within regions. A city or regional transportation commission's compliance or lack of compliance with the land use strategies outlined in the SCS should be transparent. However, a sub-region or city's overall contributions to a region's GHG reduction target will be less transparent. Evaluation of implementation measure effectiveness on a city-by-city basis could be useful in the event that a city claims it is being disproportionately burdened with implementing strategies, or seeks credit for taking additional measures to relieve implementation burdens on other areas in a region.

Conclusions

Improvements to models, evaluation, and data are needed for successful SB 375 implementation. Without these improvements, policymakers and policy evaluators will be unable to determine the success of individual policies, regional GHG target performance, and state-wide success of SB 375 as a policy. The impetus for these improvements isn't solely the a desire to accurately model GHG emissions from transportation as these model and data improvements will result in better information on transportation policy co-benefits and robust forecasts needed for underwriting of public-private financing partnerships.

While many of the needed improvements are currently underway, developing an integrated plan to coordinate and prioritize improvements will maximize return on investment and reduce dispersion of model capabilities. While models currently exhibit varying sensitivities to SB 375 policies, model dispersion is not a transitional problem. Even when all models are reasonably sensitive to all SB 375 implementation strategies, there will still be a need for model improvements, as models become useful for an expanding set of urban and regional decision-making. Future regional micro-simulation models could be used to enhance understanding of local investment decision on neighborhood dynamics at several sites or forecast the potential effects of advanced goods movement infrastructure.

Bibliography

Aben, I, O. Hasekamp, and W. Hartmann. "Uncertainties in the space-based measurements of CO_2 columns due to scattering in the Earth's atmosphere." *Journal of Quantitative Spectroscopy & Radiative Transfer*, 2007: 450.

Barth, Matthew, and Kanok Boriboonsomsin. "Real-World Carbon Dioxide Impacts of Traffic Congestion." *Transportation Research Record: Journal of the Transportation Research Board* (Transportation Research Board of the National Academies) 2058 (2008): 163-171.

Boarnet, Marlon. "Program Evaluation in Transportation: Can We Do What Other Policy Fields Do?" *Measuring Progress towards Transportation GHG Goals.* Los Angeles, CA, March 5, 2010.

Brookings Institution. "State of Metropolitan America: On the Front Lines of the Demographic Transformation." 2010.

California Air Resources Board. *2000-2006 Inventory by IPCC Category.* Sacramento, March 13, 2009.

California Air Resources Board. *California Greenhouse Gas Inventory - By IPCC Category.* Sacramento, November 19, 2007.

California Air Resources Board. *California's 1990-2004 Greenhouse Gas Emissions Inventory and 1990 Emissions Level: Technical Support Document.* May 2009.

—. "Draft Regional Greenhouse Gas Emission Reduction Targets For Automobiles and Light Trucks Pursuant to Senate Bill 375." June 30, 2010. http://www.arb.ca.gov/cc/sb375/targets/drafttargetrelease.pdf (accessed June 30, 2010).

—. "Mobile Source Emissions Inventory." January 9, 2009. http://www.arb.ca.gov/msei/msei.htm (accessed September 3, 2009).

—. "On-Road Emission Model Methodology Documentation." n.d. http://www.arb.ca.gov/msei/onroad/doctable_test.htm.

California Board of Equalization. "Motor Vehicle Fuel 10 Year Report." n.d. http://www.boe.ca.gov/sptaxprog/reports/MVF%2010%20Year%20Report.pdf (accessed November 6, 2009).

California Department of Transportation. "2000-2001 California Statewide Household Travel Survey Final Report." June 2002. http://www.dot.ca.gov/hq/tsip/tab/documents/travelsurveys/2000_Household_Survey.pdf (accessed May 25, 2010).

California Transportation Commission. "2010 California Regional Transportation Plan Guidelines." 2010.

Caltrans. "County Vehicle Miles of Travel." *Division of Transportation Systems Information.* 2010. http://traffic-counts.dot.ca.gov/monthly/StateHwy%20County%20VMT%201990-2008.xls (accessed May 11, 2010).

Cambridge Systematics. *Moving Cooler.* Urban Land Institute, 2009.

Fernández, P. C., and J. R. Long. "Grades and Other Load Effects on On-Road Emissions: An On-Board Analyzer Study." *Fifth CRC On-Road Vehicle Emission Workshop.* Alpharetta, Ga.: Coordinating Research Council, 1995.

—. "Grades and Other Load Effects on On-Road Emissions: An On-Board Analyzer Study." *Fifth CRC On-Road Vehicle Emission Workshop.* Alpharetta, Ga.: Coordinating Research Council, 1995.

Ganson, Chris. *The Transportatoin Greenhouse Gas Inventory: A First Step Toward City-Driven Emissions Rationalization.* UCTC Research Paper No. 879, Berkeley: University of California Transportation Center, 2008.

Giuliano, Genevieve. "An assessment of the political acceptability of congestion pricing." *Transportation* (Springer Netherlands) 19, no. 4 (December 1992): 335-358.

Handy, Susan. "Evaluating Policy Effectiveness." *Measuring Progress towards Transportation GHG Goals.* Los Angeles, CA, May 5, 2010.

Intergovernmental Panel on Climate Change. *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Vol. 2. 2006.

Japan Aerospace Exploration Agency. "Greenhouse gases Observing SATellite "IBUKI" (GOSAT)." November 11, 2009. http://www.jaxa.jp/projects/sat/gosat/index_e.html (accessed February 2010, 3).

John, D. Hunt, and E. Abraham John. "Design and Application of the PECAS Land Use Modelling System." Sendai, Japan, 2003.

Kahn, Matthew E., and Ryan K. Vaughn. "Green Market Geography: The Spatial Clustering of Hybrid Vehicles and LEED Registered Buildings." *The Berkeley Electronic Journal of Economic Analysis & Policy* 2, no. 9 (2009).

Koupal, J., H. Michaels, M. Cumberworth, C. Baily, and D. Brzezinski. *EPA's Plan for MOVES: A Comprehensive Mobile Source Emissions Model.* U.S. Environmental Protection Agency, 2002.

Koupal, John. "GHG Capability of U.S. EPA's Vehicle Emissions Model MOVES2010." *Presented at Measuring Progress Towards Transportation GHG Goals.* Los Angeles, March 5, 2010.

Matute, Juan. "Use of EMFAC and Fuel Use Data to Create Transportation GHG Inventories in California." 2010. http://www.lewis.ucla.edu/climate/files/useofEMFAC.pdf.

Mays, Kelly L, Paul B. Shepson, Brian H. Stirm, Anna Karion, Colm Sweeny, and Kevin R. Gurney. "Aircraft-Based Measurement of the Carbon Footprint of Indianapolis." *Environmental Science & Technology*, 2009: 7816-7823.

Park, Sangjun, and Hesham Ahmed Rakha. "Energy and Environmental Impacts of Roadway Grades." *Transportation Research Record: Journal of the Transportation Research Board* (Transportation Research Board of the National Academies), no. 1987 (2006): 148-160.

Park., Sangjun, and Hesham Ahmed Rakha. "Energy and Environmental Impacts of Roadway Grades." *Transportation Research Record: Journal of the Transportation Research Board* (Transportation Research Board of the National Academies), no. 1987 (2006): 148-160.

Regional Targets Advisory Committee. "MPO Self-Assessment of Current Modeling Capacity and Data Collection Programs." May 5, 2009. http://www.arb.ca.gov/cc/sb375/rtac/meetings/050509/mpoassessmentupdate.pdf.

Regional Targets Advisory Committee. *Recommendations of the Regional Targets Advisory Committee (RTAC) Pursuant to Senate Bill 375*. Sacramento: California Air Resources Board, 2009.

Shoup, Donald. *The High Cost of Free Parking.* Chicago: Planners Press, 2005.

Song, Bai, Douglas Eisinger, and Deb Niemeier. "MOVES vs. EMFAC: A Comparative Assessment Based on a Los Angeles County Case Study." *TRB 88th Annual Meeting Compendium of Papers DVD.* Transportation Research Board, 2009.

Southern California Association of Governments. "Year 2003 Model Validation and Summary: Regional Transportation Model." 2003. http://www.scag.ca.gov/modeling/pdf/MVS03/MVS03_Chap09.pdf (accessed August 25, 2009).

U.S. Bureau of Economic Analysis. *Gross Domestic Product by State.* June 2, 2009. http://www.bea.gov/regional/gsp/ (accessed May 14, 2010).

U.S. Bureau of Labor Statistics. *Local Area Unemployment Statistics.* May 2010. http://data.bls.gov/PDQ/servlet/SurveyOutputServlet?data_tool=latest_numbers&series_id=LASST06000003 (accessed May 14, 20010).

U.S. Energy Information Administration. *California Regular All Formulations Retail Gasoline Prices.* May 10, 2010. http://www.eia.doe.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mg_rt_ca&f=m (accessed May 14, 2010).

U.S. Environmental Protection Agency. *Technical Guidance on the Use of MOVES2010 for Emission Inventory Preparation in State Implementation Plans and Transportation Conformity.* April 2010. http://www.epa.gov/otaq/models/moves/420b10023.pdf (accessed April 27, 2010).