# Critique of Metropolitan Planning Organizations' Capabilities for Modeling Transportation Control Measures in California

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For each class of transportation control measures (TCMs), the relevant travel behaviors expected to change are identified and techniques for simulating these changes are listed. Then, the latest round of analysis of TCMs in each of the four largest urban regions in California is studied carefully to see whether the relevant behaviors were modeled in a credible fashion, on the basis of local data. In modeling TCMs that change travel time and costs or expand transit options, models were found to lack automobile ownership steps and accessibility variables in some steps. Intersection capacity and delay should be entered into the road networks, and the networks need to be more detailed. In addition, more cost data are needed. Household income should be retained in final trip tables to allow for equity evaluations of changes in travel patterns. In simulating policies that change land uses, walk and bicycle modes should be explicit, and better land use data are needed. For analysis of clean vehicle incentive programs, vehicle types should be linked to trip purposes. Most agencies did a poor job evaluating TCMs; in some cases, they did not even use their travel demand models but instead used spreadsheets with generalized default values. Many improvements are being made to these models, and practice will be improved.

The regional travel demand models of metropolitan planning organizations (MPOs) have been used in the past primarily for the undemanding task of projecting relative levels of traffic congestion or transit demand in urban corridors. The new federal Clean Air Act, however, now requires models that can project travel (and on-road mobile emissions) with absolute accuracy. Air quality plans in nonattainment regions must include transportation control measures (TCMs) and, for example, must reduce emissions of volatile organic compounds according to certain schedules (by 15 percent in 6 years or 9 percent in 3 years). Furthermore, the TCMs to be evaluated include pricing and land use measures, policies not traditionally modeled by most MPOs.

Because of the uneven quality of MPO models across the United States, and because of the incomplete and fragmented modeling regulations that have come from the Environmental Protection Agency (EPA) to date, MPOs have developed their own national guidelines for good modeling practice (*1*). Whereas that report and papers commenting on its drafts (*2*) consider regional models in general, examination of specific MPO models in the major California urban regions (the San Francisco Bay Area, Sacramento, Southern California, and San Diego) will help further understanding of how models need to be improved to simulate accurately the effects of TCMs on travel and emissions.

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We set forth an exhaustive list of desired modeling capabilities but believe that at least one MPO in the United States has realized them. We would not expect an MPO to develop all of these capabilities within the next few years, because of data limitations. However, we would expect MPOs to accelerate data collection for the next round of model development and at least attempt most of the recommended improvements. Under the Intermodal Surface Transportation Efficiency Act, many categories of funds for planning and model development are available including some types of project funds; thus, funding should not be a limitation in the future.

Apparently, environmental groups are poised to sue some of the large MPOs, at least partly on the basis of their modeling methods. Perhaps MPOs should work toward making their models close to the state of the art instead of merely acceptable according to EPA guidelines. Lawsuits can easily cost more than a major program of model development. Each MPO will have to weigh these matters considering its current models and data sets, and develop a model improvement work plan that suits its local needs. Our critique of existing models does not represent legal requirements; those are unique to each region.

Our modeling reviews were drafted in more detail than appears here and were reviewed by the agencies. We attempted to respond to staff members' concerns in every case but were often hampered because their written and oral reviews differed from the agency documents or those of other staff members. Turnover of staff also made it difficult to ensure the accuracy of some details, as did lack of documentation for some modeling exercises. In some cases, MPO reviews were antagonistic, because of past or threatened lawsuits. In all cases, we found agency staffs overworked and had to ask repeatedly for their assistance in reviewing the drafts. We have tried very hard to represent accurately the modeling practices of the MPOs.

We begin by categorizing TCMs into eight different classes and identifying the TCMs' likely behavioral effects and the model components needed to capture those effects. The categories and criteria are based on a selective review of the literature on modeling theory and practice (*3*) and on work by Harvey (*4*). Next, we discuss issues related to the criteria set out, including the magnitude of TCMs' effects, forecasting variables, the feasibility of the proposed improvements, and synergistic effects of TCMs. We then examine the MPOs' analyses of TCMs in their most recent round of transportation and air quality plans and compare their TCM analyses with our criteria to identify shortcomings. We also discuss improvements under way on their models and recommend additional improvements needed for better TCM modeling.

## CATEGORIES OF TCMs AND CRITERIA FOR ACCURATE MODELING

Categories described in this section, their behavioral effects, as well as many modeling criteria, were informed by Harvey's report (*4*).

### Change Travel Times

TCMs that alter travel times include high-occupancy vehicle (HOV) lanes, arterial operation improvements, preferential parking, and reduced transit wait times. These TCMs are designed to decrease travel times for high-occupancy modes or increase travel times for low-occupancy modes. The primary behavioral effect of these TCMs should be mode shifts. But they may also result in reduced automobile ownership, fewer and shorter trips by automobile, and closer proximity of residential and work locations.

To capture the mode shift effects of these TCMs, a reliable mode choice model is needed, one that accurately represents congested and free-flow travel times, transit and automobile access times (e.g., walk and wait), and signal and intersection delays for all trip purposes.

Currently, many models represent access to transit only crudely (*5*). The representation of transit access times can be improved by incorporating variables such as proximity of work and housing to transit, bicycle and pedestrian conditions, and the location of park-and-ride lots (*5*). The representation of automobile access times can also be improved with increased sensitivity to parking capacity constraints (*5*).

Highway and transit travel times and costs or composite impedances should be represented in the trip distribution, trip generation, and automobile ownership steps (in addition to the mode choice step, as described above) to simulate changes in trip lengths, the number of trips made, and the number of cars owned by households. It is important that an endogenous automobile ownership step be included in the travel demand model because of the significant effect of automobile ownership on trip generation. The representation of accessibility in the automobile ownership step should include parking availability (*5*). All model steps should be fully iterated on impedances from assignment (i.e., congested impedances for peak models and uncongested impedances for nonpeak models).

If these TCMs result in large changes in accessibilities, even just for some subareas, a land allocation model that is fully iterated with the travel demand model can be used to simulate changes in the location of new employment and residential development.

### Change Travel Costs

TCMs that alter travel costs include increased fuel taxes, pay-as-you-drive insurance, highway peak-period congestion fees, increased bridge tolls, parking fees, subsidized transit, ridesharing incentives, and vehicle purchase fees. These TCMs are designed to increase the monetary cost of traveling in single-occupancy vehicles and to decrease the cost of traveling in high occupancy modes. The primary result of these TCMs should be a shift in mode from single-occupancy vehicles to HOVs. In addition, these TCMs may result in fewer, shorter discretionary trips and time-of-travel shifts, particularly in the case of peak-period congestion pricing. However, reduced travel times resulting from mode shifts, reduced trip making, and time-of-day shifts may induce some single-occupant vehicles back onto facilities and thus offset some portion of the mode shift. Further, if pricing measures are imposed only on certain roadways, route shifts instead of mode shifts may occur. A secondary effect of large changes in travel pricing may be changes in employment and residential locations for existing and new land uses. Finally, issues of equity also need to be considered when evaluating travel-pricing TCMs.

The mode shift effects of these TCMs can be simulated with the use of a reliable mode choice model that accurately reflects changes in travel costs in composite impedances, as discussed above. Again, an endogenous automobile ownership step that is sensitive to travel costs (including parking costs) is needed to capture these TCMs' effects on automobile ownership levels and thus on trip generation. Generalized travel costs should also be included in the trip distribution and trip generation steps to better simulate changes in the number and length of trips made as a result of these TCMs. A departure time choice model that is sensitive to direct travel costs as well as time costs is needed to represent time-of-day shifts due to TCMs that impose additional monetary costs on peak-period travel, such as congestion pricing. To simulate these TCMs' effects on route choice, Harvey suggests that travel time components be "supplemented by a network assignment model capable of capturing the 'equilibrium' between price and time effects" (*4*). All model steps should be fully iterated on composite impedances from assignment.

Detailed pricing data in the base year data set must be available to properly specify the model's travel cost variables. Replogle suggests that the data should include information about "the share of employees getting free parking at individual sites or within compact zones, the cost of short and long term parking at individual sites or within compact zones, the cost of short and long term commercial parking, HOV pricing incentives and other commuter subsidies, as well as transit cost on an origin-destination basis (if appropriate by mode)" (*5*).

A data base or model that links vehicle types to trip categories is needed to project the emission effects of TCMs that increase costs for high-emitting vehicles (*4*).

For equity evaluation of TCMs that alter travel costs, household income classes should be retained in the final trip tables. This makes information related to the number of people by income class affected by a particular pricing policy readily available.

Again, if these TCMs result in large changes in accessibilities, a land allocation model that is fully iterated with the travel demand model can be used to simulate changes in the location of new employment and residential development.

### Expand Transit Options

TCMs that expand travel options include, for example, improved access to bus and rail transit. These TCMs are designed to expand travel options by serving areas with new modes. The primary behavioral effect of these TCMs should be mode shifts; however, large changes in transit service may affect automobile ownership levels, trip lengths, and trip generation. Heavy rail (subway or commuter rail) may also alter new land development patterns.

To accurately capture the travel demand for new modes, mode choice models ideally should incorporate unobserved attributes, such as comfort and reliability, as explicit variables in mode choice, in addition to travel time and cost. However, Harvey suggests that such variables can be difficult to quantify, and thus "conventional studies get around the problem by using observed shares to create a one-time set of adjustments"(*4*).

Because these TCMs also affect transit travel times and costs, composite impedances should be included in the mode choice, trip distribution, trip generation, and automobile ownership steps to represent changes in these behaviors. In addition, if TCMs result in large changes in accessibilities, a land allocation model should be used.

### Change Land Uses

Some TCMs encompass a range of land development policies aimed at encouraging a more compact pattern of urban development coordinated with transit services and with improvements to walking and bicycling facilities. These TCMs may result in mode shifts, shorter trips, fewer automobile trips, and reduced automobile ownership.

Generally, walk, bicycle, and transit accessibility variables (i.e., measures of the walk and bicycle environment and transit travel time and cost) are needed in the mode choice, trip distribution, trip generation, and automobile ownership steps to simulate the effects of these TCMs (*5*). More specifically, the mode choice step should include explicit walk and bicycle modes as well as indices of zonal or discrete household-based bicycle and pedestrian "friendliness" to simulate mode shifts due to these TCMs (*5*). Further, to represent the diversion of short automobile trips to nonmotorized modes, a person-trip-based trip generation step should be used in which central business district (CBD) and other locational variables have been replaced with variables that represent nonmotorized access to retail and pedestrian and bicycle friendliness (*5*). Detailed networks and smaller zones can be used to improve representation of walk, bicycle, and transit accessibility (*5*). Model steps should be fully iterated on zone-to-zone travel impedances from assignment.

To properly specify walk, bicycle, and transit accessibility variables, Replogle suggests collecting "inventories of transportation supply, with information on road widths, number of lanes, presence of medians, intersection configurations, transit services including transit stop locations and service frequency, parking inventories including park-and-ride lots, location and character of sidewalks and bicycle paths and lanes, availability of secure bicycle parking spaces at transit stops, and other factors" (*5*).

If TCMs result in large changes in accessibilities, a land allocation model should be used.

### Clean Vehicle Technology

These TCMs include vehicle technologies designed to reduce emissions, for example, technologies that change the internal combustion engine, electric vehicles, vehicle inspection and maintenance, new car standards, clean fuels, or retirement of high-polluting vehicles. Such TCMs are designed to alter the vehicle rather than travel behavior.

For TCMs that affect the entire fleet in a uniform manner, Harvey suggests that "emissions improvements can be calculated simply by substituting a revised set of composite emission factors" (*4*). Harvey has pointed out the difficulties in evaluating emission reductions for TCMs that affect only a portion of the fleet (*4*):

> There is a danger that the altered portion of the fleet will be used in a way that is not representative of the overall vehicle use pattern. Two clear examples come to mind: (1) conversion of a dedicated fleet to alcohol or electric propulsion might have a disproportionately small effect on emissions because so much of fleet VMT occurs in the hot stabilized operating regime; and (2) subsidized or mandated retirement of the oldest personal vehicles might have a disproportionately large effect on emissions because so much of the VMT of the old vehicles occurs in the cold and hot start modes. Simple adjustment of the fleet composite emissions factors would not accurately represent either of these changes.

Partial fleet changes should be evaluated with a model or data base that links vehicle types to trip categories in addition to having revised emission factors (*4*). If vehicle or fuel costs rise uniformly, these changes can be simulated, as discussed earlier with respect to TCMs that change travel costs.

### Ease Activity Constraints

These TCMs attempt to reduce the place and time restrictions of work travel that force travelers to use limited transportation services. Examples of TCMs that ease activity constraints are flextime and telecommuting. The behavioral effects of these TCMs are highly complex; however, they should affect mode choice, departure time choice, trip making, and possibly automobile ownership.

Models of human activity scheduling behavior can capture the effects of flextime and telecommuting, but as yet these models exist only in experimental form (*4*). Without such models, the behavioral effects of these TCMs must be assessed by extrapolating from carefully interpreted case study data and manually adjusting mode choice projections (*4*), trip generation rates, and possibly automobile ownership rates. However, a time-of-day choice step that is included in the travel demand model can help simulate changes in travelers' choice of departure time resulting from flextime policies.

### Promote Alternative Modes

TCMs that promote alternative modes are designed to educate travelers about their travel options and thus help them make more rational travel decisions. Such promotion can be very effective where modal choices are substitutable. These TCMs should result primarily in mode shifts.

Currently, it is very difficult for travel demand models to simulate the effects of promotional TCMs. Case studies, if carefully interpreted, can be used to manually adjust the mode choice projections (*4*).

### Limit Travel Options

These TCMs are intended to reduce modal options (i.e., use of automobiles) either temporarily or in the long term and include, for example, fuel rationing and exclusion of single-occupant automobiles from key facilities. In the short term, these TCMs may result in large mode shifts, reduced trip making, and shorter trips. If enacted frequently or in the long term, these TCMs may result in changes in automobile ownership, and changes in new and existing residential and employment location might occur.

To reflect reduced modal options on key facilities, Harvey cites the need for a detailed network of freeways, arterials, and roads as well as a "mode choice model with a 'choice set' (i.e., range of alternatives) that can be adjusted to reflect limited availability" (*4*).

Because TCMs that limit travel options will increase the time and cost of automobile travel, composite impedances that reflect these increases should be represented in the mode choice, trip distribution, trip generation, and automobile ownership steps. If TCMs result in large changes in accessibilities, a land allocation model should be used.

## TCM EFFECTS WARRANT MODEL IMPROVEMENTS

Wachs, in a comprehensive review of recent behavioral research in transportation demand management, found that there is clear evidence that travel time, out-of-pocket travel costs, and the comfort and reliability of travel modes have a significant effect on trip generation, mode choice, departure time choice, and route choice (*6*). Stopher summarizes the literature on the effects of capacity constraints (e.g., congestion, which increases the time costs of travel) on travel behavior and concludes that such constraints result in changes in new development, automobile ownership, trip making, the length of trips, mode choice, departure time choice, and route choice (*7*).

Bae, however, in an examination of transportation and land use measures included in Southern California's Air Quality Management Plan (particularly, alternative work schedules, mode shift strategies, and growth management), found that these measures were projected to have a relatively modest impact on reducing air pollution (*8*). It should be noted that Bae's examination made use of some weak sources. Bae suggests that clean vehicle technology and pricing TCMs are more effective alternatives. Cameron's study of pricing policies in Southern California found that pricing policies would have a significant effect on trip generation, VMT, and mode choice. The Transportation Incentive Planning System (TRIPS) travel demand model, which includes an endogenous automobile ownership step and composite travel costs throughout the model hierarchy, was used for this study (*9*).

In the end, however, transportation planners must use their own judgment as to whether the effects of particular TCMs in a particular region will be large enough to warrant the model improvements suggested here, particularly inclusion of composite impedances in the trip generation and automobile ownership steps and feedback to those steps and to a land allocation model.

## FORECASTING TCM VARIABLES

Most of the variables at issue in this paper, (i.e., accessibility and demographic variables) are currently forecast in most regional travel demand models. Life-cycle stage variables, which have been shown to be significant in predicting travel demand, are less commonly forecast in regional travel demand models. However, the Portland, Oregon, and Montgomery County, Maryland, models have incorporated life-cycle variables (e.g., ages of household members). Forecasts of these variables are likely to be reasonable within a 20-year time frame. Because land use forecasts are subject to local political pressures, we advocate simulation of land use variables through land allocation models (i.e., development location choice models) to avoid political bias and improve accuracy.

## FEASIBILITY OF PROPOSED CHANGES

Travel time and travel cost variables can be included throughout the chain of travel demand models. The original Metropolitan Transportation Commission models (1978) are an example of a set of regional travel demand models that have successfully incorporated composite impedances in the mode choice, trip distribution, trip generation, and automobile ownership steps. Land allocation models that are sensitive to transportation supply are available (e.g., the DRAM/EMPAL model); however, their sensitivity is limited (*7*).

Separate walk and bicycle modes can be added to mode choice models fairly easily. The difficulty arises in developing the travel times for these modes. Greatly increased network detail is needed to estimate travel times for short walk and bicycle trips (*7*). In the short term, however, rough approximations of walk and bicycle travel times can be derived from the roadway network. The integration of geographic information systems into travel demand models will assist in the development of the network detail needed for improved specification of walk, bicycle, and transit accessibilities. In the short term, however, zonal and discrete household-based walk, bicycle, and transit accessibility indexes have been incorporated effectively into some regional travel demand models, for example, that of Montgomery County, Maryland.

Currently, time-of-day choice modes are not generally included in regional travel demand models. Stopher states that "some form of time-of-day modeling can be developed to work within travel-forecasting procedures" (*7*). Portland, Oregon, and Sacramento, California, are incorporating explicit time choice components in their updated travel demand models (*1*).

Comfort and reliability variables are difficult to incorporate in regional travel demand models. However, academic models have successfully incorporated such variables (*10*). Wachs suggests the use of market segmentation to help clarify the relationship between attitudes and travel behavior (*6*).

Finally, the additions and extensions suggested in this paper require data that are not generally included in conventional data bases used to estimate and calibrate models. Conventional data bases should be expanded to obtain needed travel behavior data. Such estimation and calibration of model steps and of overall system models is more time-consuming than past practices. However, Portland has calibrated its socioeconomic/demographic models (i.e., worker, children, and automobile ownership models) and travel demand models (i.e., trip generation, destination choice, pre-mode choice, and mode choice models) to survey data and has calibrated its automobile assignment and transit assignment models to count data.

## SYNERGISM

TCMs tend to be modeled separately instead of together as a package. However, some combinations of TCMs can increase or decrease the effectiveness of individual TCMs (*11*). The findings regarding potential synergistic effects were summarized as follows (*11*):

> In general, it was found that improvements in driving conditions work counter to efforts to shift commuters from their own cars onto public transit or to participate in ridesharing programs. Penalties associated with driving, on the other hand, support these efforts, as well as attempts to reduce overall travel by changing land uses and substituting communications for work trips. All transit improvement and incentive techniques are mutually supportive to a high degree. Carpooling, which in itself appears to be a moderately effective and inexpensive approach, does not blend well with many other approaches; efforts to reduce travel demand by changing land use, to spread peak commuting time, to provide transit alternatives, or to improve traffic flow through improvements to roadways all reduce the motivation for participating in prearranged ridesharing.

Thus, TCMs should be modeled in various packages, not separately, to capture synergistic effects and thereby avoid overestimating or underestimating the effects of TCMs.

## PAST TCM MODELING PRACTICES IN FOUR REGIONS

This section and the next are based on a study performed for the California Energy Commission that reviews the MPOs' regional travel demand models and their modeling of TCMs (*3*). Agency documents and interviews were used to prepare these reports, and the reports were reviewed by the agencies for accuracy.

### San Francisco Bay Area

The TRIPS model was the primary travel demand model used in the San Francisco Bay Area to evaluate TCMs. TRIPS was used to evaluate most TCMs within the travel cost category and some TCMs within the travel time category. Local data, empirical studies reported in the literature, and interviews with experts were used for categories of TCMs involving expanded travel options, travel time, land use changes, activity constraints, and promotion of alternative modes (*12,13*). TCMs involving walk and bicycle improvements were modeled with "a regional mode choice model developed by Deakin in the mid 1980's with bicycle and walk as explicit modes" (*12,13*). Traffic operations models, such as TRANSYT and NETSIM, were also used in the analysis (*13*).

The TRIPS model was derived from models originally developed for the Metropolitan Transportation Commission in the mid- to late 1970s; it incorporates transit and highway travel times and costs in all of its model steps, includes an automobile ownership step, and is fully iterated (*14*). TRIPS uses a sample of households from the most recent Bay Area travel survey, which preserves the variation in the distribution of population characteristics and thus produces more accurate travel demand predictions (*15*). Household totals are expanded to represent the larger population and summed in regional categories (*15*). TRIPS lacks a detailed network representation and traffic assignment component. Instead, as an approximation, a simple routing for estimating changes in level of service has been incorporated in the model. Thus, TRIPS achieves great detail in representing demand at the expense of detailed network representation (*14*).

### Sacramento Region

As part of the regional mobility plan, the Sacramento region used its regional transportation demand model to evaluate parking pricing and new HOV lanes (*16,17*). Cumulative estimates of VMT and emission reductions due to the other TCMs included in the plan were derived from the results of TCMs modeled by other regions in California, particularly the Bay Area (*17*). Analyses of TCM effectiveness in the Bay Area and other areas cannot be transferred credibly to the Sacramento region, however, because of large differences in urban structure and transportation infrastructure, particularly modal options.

### Southern California Region

For its 1992 Air Quality Management Plan, the Southern California region used its regional travel demand model to evaluate TCMs involving alternative work weeks, flextime, telecommuting, employer rideshare and transit incentives, parking management, vanpool purchase incentives, merchant transportation incentives, automobile use restrictions, new HOV facilities, and transit improvements, as part of its regional mobility plan (*18*). These strategies were modeled primarily through manual adjustments to the trip generation tables and mode choice model. In other words, each TCM was assumed to reduce single-occupant vehicle trips by a certain percentage, and trip generation rates and mode choice projections were adjusted to reflect that reduction (*18*). That method of modeling is not adequate because it begs the question of whether the TCMs will have their anticipated behavioral effects. Some strategies that involve pricing incentives were modeled correctly with sensitivity runs, which resulted in changes in mode choice (*3*).

The Southern California region modeled TCMs related to goods movement, traffic flow improvements, nonrecurrent congestion relief, airport ground access, and rail consolidation with elasticities obtained from the regional travel demand model and from elasticities reported in the literature (*3,18*). Elasticities that are used to adjust VMT or trips without running these changes through the model set will not represent the complete effects of the TCMs, however. Also, point elasticities obtained from the literature are valid only if they are used for the same ranges and starting points on the basis of which the elasticities were calculated.

### San Diego Region

The San Diego Region evaluated its TCMs with the use of TCM Tools (*19*), a spreadsheet that aggregates the effects of TCMs at the regional level and uses input data obtained from expert judgment. The spreadsheet has default values for most outputs or uses point elasticities to produce outputs. The default values can be overridden with area-specific data obtained from a regional transportation model. The spreadsheet does not represent the effects of changes in congestion on travel. Most of the effects of land use changes and traffic flow improvements must be estimated apart from the spreadsheet. In general, the spreadsheet is primarily a screening tool and generally predicts the best, instead of the most likely, outcomes of TCMs (*15,20*).

The TCM Tools spreadsheet is acceptable as an accounting system for measuring the effects of TCMs only if it is used in conjunction with a fully run set of regional travel demand models and its default values are overridden with area-specific values obtained from the regional travel demand model.

Most default values were not overridden in the modeling of the San Diego region's TCMs. Small adjustments were made for some default values for the HOV and park-and-ride TCMs. Because the elasticities were so small and it was thought that area-specific values would not be much different from the default values, no area-specific adjustments were deemed necessary. In general, the San Diego region lacks data with which to develop area-specific values (*3*).

## MPOs' POTENTIAL ABILITIES TO ANALYZE TCMs

### Current Models

As described above, not all TCMs in the regions that should have been were modeled with regional travel demand models. However, accurate evaluation of most TCMs requires that analyses be performed by fully run travel demand models. Therefore, regional travel demand models' current abilities, if they were used to evaluate the categories of TCMs, were examined to identify needed model improvements.

Categories of TCMs related to changes in travel time, changes in travel cost, and expanded transit options can only be evaluated adequately with TRIPS, particularly if it is used in conjunction with a network (assignment) model. That is primarily because TRIPS incorporates highway and transit travel time and cost in its mode choice, trip distribution, trip generation, and automobile ownership steps and the model is fully iterated. The Sacramento, Southern California, and San Diego regions incorporate highway and transit travel time directly only in the mode choice and trip distribution steps and incorporate travel cost directly only in the mode choice step. However, travel cost is included indirectly in the Southern California and San Diego regions' trip distribution steps through feedback. None of these three regions has an automobile ownership model that is endogenous and is affected by accessibility or by other variables that can be altered with policy. The Sacramento region does not recycle assigned travel impedances back to trip distribution.

To improve the accuracy of travel times in the models, all MPOs should improve their representation of access to transit and automobile in the mode choice step. Further, only San Diego's model represents signal and intersection delay separately from link capacity and delay. None of the models include explicit comfort and reliability variables to capture demands for expanded travel options accurately. To simulate the effects of TCMs that increase the monetary cost of peak-period travel (e.g., congestion pricing), all of the MPOs need to develop time-of-day choice models. In addition, only TRIPS retains income in all the trip tables, which allows analysis of the equity implications of pricing measures.

All of the MPOs have pricing data related to automobile operating costs, tolls, transit fares and discounts, and some parking cost data. The Bay Area region has daily and monthly parking cost data. The San Diego region's parking data are adequate except that more data are needed regarding the share of employees with free parking. Sacramento has parking cost data (monthly zonal averages) only for the downtown area and none for suburban or special generator areas.

None of the regions use travel demand models that can evaluate adequately TCMs that improve walk, bicycle, and transit environments. None of the regions represent walk and bicycle modes separately in the mode choice step except for the San Diego region, and its walk and bicycle modes are not policy sensitive (they are exogenous). In general, walk, bicycle, and transit accessibility variables (for example, proximity of employment and housing to transit and services, and walk and bicycle characteristics of zones) are lacking in the mode choice, trip distribution, trip generation, and automobile ownership steps. The Bay Area and Sacramento regions are able to represent, to some degree, the homogeneity and heterogeneity of land uses, because they include a variable for employment in the zone of residence. All MPOs should replace CBD and other locational variables with variables that represent regional accessibility and improve the detail of their networks to represent the proximity of employment and housing to transit and services. The regions all use reasonably small zones in areas of dense land use.

All the regions lack sufficient transportation and land use supply data, particularly related to zonal walk and bicycle characteristics. All have transportation supply data related to the transit and automobile travel times, roadway lanes, park-and-ride lots, and transit stops. Only the San Diego region has data on intersection configurations, parking inventories, and walk and bicycle distance. All need data related to the character of sidewalks, bicycle paths and lanes, availability of secure bicycle parking spaces at transit stops, and roadway medians.

For TCMs related to clean vehicle technology, all regions can calculate emission improvements from TCMs that affect the entire fleet in a uniform manner by substituting a revised set of composite factors. None has the capacity yet to evaluate partial fleet changes with regional models. However, some data are available on vehicles from the California Department of Motor Vehicles, which could be used in conjunction with the TRIPS model (and perhaps other models) to evaluate the effects of this TCM (*4*).

For categories of TCMs related to promotion of alternative modes and to the easing of activity constraints (e.g., flextime and telecommuting), all regions can use carefully interpreted case studies to manually adjust their mode choice projections. All MPOs use case study data, but available documentation suggests that none, except the Southern California region, used them to manually adjust mode choice projections.

Only the Southern California and Sacramento regions included TCMs intended to limit travel options. However, to model these TCMs, all the regions would need to improve the detail of their networks (i.e., obtain a more detailed depiction of roadways in restricted areas) and use an adjustable choice set in their mode choice models.

To assess secondary effects of changes in new residential and employment locations due to TCMs, only the Southern California region iterated the travel demand projections with land allocation model projections. The Bay Area and San Diego regions could do this, but they did not do so for their TCM analyses. The Sacramento region currently does not have a land allocation model. None of the regions used alternative land use projections as a TCM, although all of them have done such studies in the past.

**Planned Model Improvements**

The San Francisco Bay Area plans to pursue the following travel demand model improvements, which should improve their ability to analyze TCMs: (*a*) incorporate walk and bike accessibility (land use) variables in the trip generation step; (*b*) develop a mode of access to rail, investigate land use density effects on transit ridership, compare generic with mode-specific time and cost parameters, and examine HOV time saving coefficients in the mode choice step; (*c*) improve the forecasting method for projecting vehicle occupancy rates, especially for nonwork trips; and (*d*) develop time-of-day choice models (*21*). These changes should be incorporated into the TRIPS model if it is used for future TCM evaluations.

The Sacramento region is currently undertaking a major update of its travel demand models and plans to incorporate the following: (*a*) an automobile ownership step that is sensitive to walk and bicycle accessibility (land use) variables and to transit access; (*b*) a trip generation step that is also sensitive to land use variables; (*c*) a mode choice step in which walk and bicycle modes are represented and zonal indexes of pedestrian and bicycle friendliness are incorporated; (*d*) travel cost variables in all model steps; (*e*) a time-of-day choice model (*22*); and (*f*) more data related to the pedestrian and bicycle environment of zones (*23*). The Sacramento region is also considering a land allocation model and is gathering the needed land use data (*23*).

The Southern California Association of Governments currently is preparing its strategic plan for improving its model, and thus the

**TABLE 1 Improvements Needed in Regional Travel Demand Models To Evaluate Transportation Control Measures**

| | CHANGE TRAVEL TIME, CHANGE TRAVEL COSTS, AND EXPAND TRANSIT OPTIONS |
|---|---|
| BAY AREA | 1. improve access to transit and auto<br>2. explicit comfort and reliability variables in mode choice<br>3. fully iterate with a land allocation model<br>4. signal and intersection capacity and delay separate from link<br>5. time-of-day choice |
| SACRAMENTO | 1. an auto ownership step<br>2. travel time and travel cost in all steps<br>3. recycle congested impedances back to auto ownership<br>4. explicit comfort and reliability variables<br>5. retain income in final trip tables<br>6. signal and intersection delay separate from link<br>7. time-of-day choice<br>8. more detailed pricing data<br>9. full iteration with a land allocation model |
| SOUTHERN CALIFORNIA | 1. an auto ownership step<br>2. travel time and travel cost in all steps<br>3. recycle congested impedances back to auto ownership<br>4. explicit comfort and reliability variables<br>5. retain income in final trip tables<br>6. signal and intersection capacity and delay separate from link<br>7. time-of-day choice |
| SAN DIEGO | 1. an auto ownership step<br>2. travel time and travel cost in all steps<br>3. recycle congested impedances back to auto ownership<br>4. explicit comfort and reliability variables<br>5. retain income in final trip tables<br>6. time-of-day choice<br>7. more detailed pricing data |

*(continued on next page)*

association was able to provide us only with information about its proposed mode choice model improvements. It is considering incorporating the following into its mode choice step: (*a*) expanded subdivisions of modes, whereby transit may be subdivided into bus, commuter rail, and rail transit, for example (however, explicit walk and bicycle modes are not being considered because variables that influence their use are difficult to quantify); (*b*) improved representation of highway terminal times, automobile and walk access to transit, automobile parking cost, and automobile operating costs; and (*c*) increased market segmentation, which may include expanded trip purposes, household income or automobile ownership, other household characteristics (e.g., household size, number of workers, and number of children), parking pricing, and travel time of day (*24*).

The San Diego region planned, by the end of 1992, to (*a*) consider incorporating trip-chaining and accessibility in the trip generation step; (*b*) include direct travel costs in impedance measures in the trip distribution step; (*c*) improve feedback mechanisms, where possible; (*d*) consider adding a light rail mode; (*e*) double modeled roadway mileage and code separate HOV facilities in the network; and (*f*) add simultaneous HOV trip table assignment (*25*).

## CONCLUSIONS REGARDING MPOs' NEAR-TERM CAPABILITIES

The Bay Area, using the TRIPS model and incorporating the model changes under way, will be the best equipped to capture the effects of TCMs involving changes in travel times and costs and expanded transit options, primarily because TRIPS incorporates travel time and travel cost in all model steps and recycles assigned impedances back through automobile ownership and subsequent steps. Generally, the other regions incorporate travel time and travel cost only in their mode choice and trip distribution steps, and assigned impedances are recycled, at best, only back through trip distribution. However, Sacramento and San Diego plan to expand their inclusion of travel time and cost in more model steps, as described above, which will improve their analyses of these TCMs. Both the Sacramento and Bay Area regions are taking steps to improve their models' depictions of peak spreading. Sacramento is also planning to develop an automobile ownership model. Items in the "Change Travel Time, Change Travel Costs, and Expand Transit Options" box in Table 1 that the regions still need to add to their programs for model improvements are as follows: Bay Area,

**TABLE 1** *(continued)*

| | CHANGE LAND USES |
|---|---|
| BAY AREA<br>SACRAMENTO<br>SOUTHERN CALIFORNIA<br>SAN DIEGO | 1. fully represent walk and bike modes<br>2. walk, bike, and transit accessibility variables in all model steps<br>3. more transportation and land use supply data<br>4. regional accessibility variables, not CBD<br>5. improve network detail |

| | CLEAN VEHICLE TECHNOLOGIES |
|---|---|
| BAY AREA<br>SACRAMENTO<br>SOUTHERN CALIFORNIA<br>SAN DIEGO | 1. a model or data base that links vehicle types to trip categories |

| | EASE ACTIVITY CONSTRAINTS |
|---|---|
| SOUTHERN CALIFORNIA | 1. when available, use model of human activity scheduling |
| BAY AREA<br>SACRAMENTO<br>SAN DIEGO | 1. careful interpretation of case studies to manually adjust mode choice projections<br>2. when available, use model of human activity scheduling |

| | PROMOTION OF ALTERNATIVE MODES |
|---|---|
| BAY AREA<br>SACRAMENTO<br>SAN DIEGO | 1. careful interpretation of case studies to manually adjust mode choice projections |

| | LIMIT TRAVEL OPTIONS |
|---|---|
| BAY AREA<br>SACRAMENTO<br>SOUTHERN CALIFORNIA<br>SAN DIEGO | 1. improve network detail<br>2. use an adjustable choice set |

2, 4; Sacramento, 4–6, 9; Southern California, all; and San Diego, 1, 3, 4–7.

Currently, all the regions have a limited ability to evaluate TCMs related to changes in land uses (i.e., improved walk, bicycle, and transit accessibility). In general, the MPOs can all improve their models' abilities to evaluate these TCMs by representing walk and bicycle modes in the mode choice step; including walk, bicycle, and transit accessibility variables in all model steps; and obtaining more detailed land use and transportation supply data. Sacramento plans to incorporate expanded land use variables in the automobile ownership, trip generation, and mode choice steps, and the Bay Area is considering incorporating more land use variables in the trip generation and mode choice steps. Sacramento is adding walk and bicycle modes. The other regions should attempt this. Sacramento should acquire a land allocation model.

To evaluate TCMs related to clean vehicle technology, all the MPOs will have to develop a model or use a data base that can link vehicle types to trip categories. Available documentation suggests that none of the MPOs has plans to develop that capability.

Carefully interpreted case studies can be used to manually adjust mode choice projections in evaluating TCMs that promote the use of alternative modes or that impose activity constraints. However, models of human activity scheduling should be used as they become available. Finally, all the MPOs should be able to model TCMs that limit travel options by increasing their network detail and using an adjustable choice set in the mode choice model.

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