Title

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A MULTI-OBJECTIVE ANALYSIS OF REGIONAL TRANSPORTATION AND LAND DEVELOPMENT POLICIES

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ABSTRACT

To address roadway congestion problems, communities throughout the nation that are at risk for air quality problems are proposing major and costly beltway highway projects. In this study, an integrated land use and transportation model and an advanced travel demand model linked to a land allocation model are applied to evaluate different combinations of transit and highway investment alternatives, land use measures, and an auto pricing policy in the Sacramento region. Four policy and methodological questions are addressed in the simulation and evaluation of policy scenarios in this case study. First, what are the respective models' strengths and weaknesses, and what effect does this have of their evaluation of policies. Second, can transit investment, auto-pricing policies, and land use measures be just as, or more, effective in reducing congestion as highway alternatives and have the added benefit of improving air quality and protecting environmentally sensitive lands? Third, what is the relative significance of the results of the alternative scenarios simulated, given plausible errors in socio-economic projections? Fourth, can auto-pricing policies alone and/or in combination with other transit and land use policies significantly reduce vehicle emissions without imposing monetary losses on travelers? Finally, the implications of the answers to these questions are examined in the context of the transportation planning process.

INTRODUCTION

To address roadway congestion problems, communities throughout the nation that are at risk for air quality problems are proposing major and costly beltway highway projects (i.e., Route 710 in California, the Grand Parkway in Houston, Texas, and the Legacy Highway in the Salt Lake City, Utah, region). The methods typically used to evaluate the effectiveness of these highway projects may be limited because they do not fully represent induced travel effects, that is, how increases in roadway supply will lower auto travel time costs and increase travel demand. As a result of their failure to represent induced travel effects, agencies' tools may tend to overestimate congestion reduction and underestimate emissions and air quality problems resulting from new highway projects. Moreover, the environmental impact statements used to evaluate the environmental impacts and the effectiveness of proposed new highway projects may not adequately identify and evaluate alternatives to highway projects.

In this study, an integrated land use and transportation model, the Sacramento MEPLAN model, and an advanced travel demand model linked to a land allocation model, the UPLAN/SACMET model, are applied to evaluate different combinations of transit and highway investment alternatives, land use measures, and an auto pricing policy in the Sacramento, California, region. The application of the Sacramento MEPLAN model and the UPLAN/SACMET models is relatively advanced because the models represent a number of induced travel effects including land use, destination, mode choice, and route choices. A number of policy and methodological questions are addressed in the simulation and evaluation of policy scenarios in this case study:

1. What are the respective models' strengths and weaknesses, and what are the implications with respect to policy evaluation?

2. Can transit investment, auto-pricing policies, and land use measures be just as, or more, effective in reducing congestion as highway alternatives and have the added benefit of improving air quality and protecting environmentally sensitive lands?

3. What is the relative significance of the results of the alternative scenarios simulated, given plausible errors in socio-economic projections?

4. Can auto-pricing policies alone and/or in combination with other transit and land use policies significantly reduce vehicle emissions without imposing monetary losses on travelers?

MODELS

Two land use and transportation models, the Sacramento MEPLAN model and the UPLAN/SACMET model are used to simulate the land use and travel effects of the study scenarios. The UPLAN/SACMET model is an advanced travel demand model (SACMET) linked to a land allocation model (UPLAN). In the UPLAN model, travel time and cost (by mode and zone pair) provided by the SACMET model affect the location of regional household and employment activities. This model provides detailed representation of travel behavior and geography. The Sacramento MEPLAN model is an integrated land use and transportation model that is more theoretically comprehensive than the UPLAN/SACMET model. The Sacramento MEPLAN model represents the regional economy and land market, redevelopment, and the effect of travel time and cost on the location of activities. Its representation of travel behavior and geography, however, is more aggregate than the representation in the UPLAN/SACMET model. (For more detailed documentation, see Hunt and Simmonds, 1993; Hunt and Echenique, 1993; Hunt, 1994; Hunt et al., 2002, Abraham and Hunt, 2001, Abraham, 2000; and DKS & Associates,1994). The travel output data from the land use and transportation models are used in the emissions models to evaluate the regulated vehicle emissions effects of the scenarios.

A cost and benefit measure that uses travel time and cost data for all modes by origin and destination pairs by household income groups is developed with the travel output from the Sacramento MEPLAN model. The benefit analysis adapted the following compensating variation formula (CV) to suit the specifications of the Sacramento MEPLAN mode choice model (Small and Rosen, 1981):

$$CV = 1/\lambda \left\{ \left[\ln \sum_{m \in M} e^{V_m(p^f)} \right] - \left[\ln \sum_{m \in M} e^{V_m(p^0)} \right] \right\} \quad (1)$$

where λ is the individual's marginal utility of income, V_m is the individual's indirect utility of all m choices, p^0 indicates the initial point (i.e., before the policy change), and p^f indicates the final point (i.e., after the policy change). The change in indirect utility is converted to dollars by the factor, $1/\lambda$, or the inverse of the individual's marginal utility of income. In the work trip purpose, households are segmented into income categories, and person trips are generated for those categories. To obtain the benefit for each income category, the formula was applied for all modes and for all trips between all origins and all destinations. The measure does not include capital and operation and maintenance costs or externalities of scenarios. Values of the marginal utility of income were obtained from model parameters estimated from local data. This measure allows for the evaluation of the relative costs and benefits of the scenarios for the region as a whole and by income class to suggest equity effects.

SCENARIOS

Table 1 provides a summary of the core study policies that are examined alone and in different combinations in this study. These core study policies include transit and highway investment, auto-pricing policies, and land use measures. These scenarios build on evaluations conducted in other simulation studies in the Sacramento region including Rodier et al., 2002; Johnston and Rodier, 1999; Rodier et al, 1998; Johnston and Rodier, 1998; and Rodier and Johnston, 1997).

Table 1. Summary of core study policies.

2020 Scenarios	Description
1. Base Case	Financially conservative expansion of the system; similar to a three-year transportation improvement program.
2. High Occupancy Vehicle Lanes (HOV)	153 new HOV lanes and six percent increase in mixed-flow freeway lanes.
3. Beltway	591 new highway lane-miles, six new beltway interchanges, 65 lane-miles of new arterial roads, and 153 lane miles of new HOV lanes.
4. LRT	153 new track miles of light rail.
5. Advanced LRT	Advanced transit information systems and/or local paratransit service are added to LRT.
6. Pricing	VMT tax ranging from one to five cents per mile.
7. Urban Reserve and Infill Subsidy	A restriction on development on vacant, residential, low-density land to protect important habitats and an infill subsidy land use measure of 20 percent of expenditures on land rent in the zones around transit stations.
8. Urban Growth Boundary (UGB)	Restricts development in slow and no-growth areas on the periphery of the region that are considered environmentally sensitive.

DISCUSSION

1. What are the respective models' strengths and weaknesses, and what are their implications for policy evaluation?

Because the UPLAN/SACMET and the Sacramento MEPLAN models capture different theoretical and structural representation of the system, the policies of interest must be operationalized differently in the models. The process of operationalizing the policy sets exemplifies the theoretical and structural differences in the models, in other words, what aspect of the policy can be represented and what aspect must be ignored. It was not possible to simulate the infill subsidy policy with the UPLAN/SACMET model because this model, unlike the Sacramento MEPLAN model, does not represent the regional land market (Rodier et al., 2002). The Sacramento MEPLAN model can represent tax and subsidies policies to encourage certain development patterns, but the UPLAN/SACMET model cannot (Rodier et al., 2002). However, because the UPLAN/SACMET model makes use of smaller zones, improvements in the pedestrian and bicycle environment could be represented in the model (Rodier et al., 2002).

A comparison of the results from multiple models illustrates the implications of the respective models' strengths and weaknesses in the evaluation of alternative policy strategies (Rodier et al., 2002). There were many differences between the two models' projections of land use changes given the same or similar transportation scenarios. Some of these differences may be explained by the theoretical differences in the model; however, it is possible that some of these differences may also be explained by differences in the travel models. The UPLAN land allocation model will only locate households and employment based on relative accessibility and available land. The Sacramento MEPLAN model is more theoretically comprehensive. The land use results shows how

a. In some instances, the representation of redevelopment in the Sacramento MEPLAN produces patterns of regional land use that are less diffused than those produced by the UPLAN model;

b. The representation of economies of agglomeration in the Sacramento MEPLAN model created an important regional economic and employment centers (i.e., the Rancho Cordova and Folsom areas);

c. The calibrated parameter for household attractions (i.e., quality of life effects, including schools, crime, and parks) in the Sacramento MEPLAN model may explain differences in household location; and

d. The representation of the regional economy in the Sacramento MEPLAN model can show the effect of improved regional accessibility on attracting new households and employment from outside the region.

In general, the differences in the land use results between the two models did not tend to change the rank ordering of the scenarios; however, the magnitude of change tended to be greater for the scenarios simulated with the Sacramento MEPLAN model compared to scenarios simulated with the UPLAN/SACMET model. Differences in land use projections between the Sacramento MEPLAN and the UPLAN/SACMET scenario simulations may contribute to the differences in the magnitude of change for the scenarios. The travel models in the two model sets may also contribute to these differences in magnitude of change. The SACMET model is a state-of-the-practice travel demand model that uses a detailed zone system and networks. The Sacramento MEPLAN model uses a comparatively simple travel demand model with large zones and a sketch network. Compared to the SACMET model, fewer resources were invested in the travel model of the Sacramento MEPLAN model. The SACMET model is used for official regional planning purposes, while the Sacramento MEPLAN model was developed for research purposes at the University of California at Davis. The use of large zones and sketch networks in the Sacramento MEPLAN model may exaggerate the effects of congestion reduction from transportation policy scenarios (Hunt et. al., 2001).

An uncalibrated version of the UPLAN model was used in this study. This model has not been implemented by the regional transportation agency (SACOG) for official purposes because of difficulties encountered in the calibration of the model, in particular, with respect to matching agency household and employment projections. It appears that the limited theoretical basis of the UPLAN model may make it difficult to calibrate. Some of the big appeals of the UPLAN model are the relatively low cost of development, its transparency, and the ability to integrate it with an existing travel demand model. Increasing the theoretical basis of the model in order to calibrate it may considerably increase the cost of its implementation. When resources are not available to develop a more sophisticated land use model, the best use of the UPLAN model may be to use it uncalibrated as a heuristic tool to explore possible effects of new capacity and land use measures. In addition, the results of the UPLAN model could be reviewed and adjusted by an expert panel to use for official planning purposes. The regional planning agency has improved and integrated the Sacramento MEPLAN model with the SACMET model for official planning purposes.

2. **Can transit investment, auto-pricing policies, and land use measures be just as, or more, effective in reducing congestion as highway alternatives and have the added benefit of improving air quality and protecting environmentally sensitive lands?**

This question is addressed by simulating combinations of transit investment, auto-pricing policies, and land use measures with the Sacramento MEPLAN model and the UPLAN/SACMET model and by evaluating these scenarios against criteria of (1) congestion reduction, (2) emissions reduction, (3) protection of environmentally sensitive lands, and/or (4) total regional benefits and benefits by income class. As Alonso (1968) asserts, the intersection of two uncertain models may produce more robust results than one grand model. The results are presented in Table 2 below.

In the Sacramento MEPLAN simulations, all the scenarios produce greater increases in auto travel speeds compared to the HOV lane scenario, and all the scenarios, with the exception of the LRT only and VMT Pricing only scenarios, produce greater increases in auto travel speeds compared to the Beltway scenario. In the UPLAN/SACMET simulations, all the scenarios, with the exception of the VMT Pricing only scenario, produce reductions in vehicle hours of delay (VHD) that were greater than those in the HOV lane scenario. In general, these results suggest that LRT combined with advanced transit service (e.g., paratransit feeder service and/or traveler information systems), auto-pricing policies, and/or land use measures may provide equivalent or greater reductions in congestion relative to the highway alternatives.

The congestion reduction results of the scenarios simulated with the Sacramento MEPLAN model and the UPLAN/SACMET model influence the location of activity and/or land consumption in the region. The results for both models indicate that the highway-oriented scenarios may allow for greater net decentralization of regional activities and/or an increase in total regional and outer ring land consumption relative to the other scenarios examined in this study. In the Sacramento MEPLAN model, the VMT Pricing policy only scenario also indicates an increase in total regional and outer ring land consumption because of reduced congestion. The LRT and Advanced LRT scenarios in the Sacramento MEPLAN model tend to decentralize activity location somewhat (i.e., shift from urban to suburban locations), but total regional and outer ring land consumption remains relatively unchanged. In contrast, in the UPLAN/SACMET scenarios, the Advanced LRT and VMT Pricing scenarios tend to reduce activity location in the outer ring of the region. In both the Sacramento MEPLAN and UPLAN/SACMET models, the land use measures effectively reduce activity location and/or total and outer ring land consumption.

In both the Sacramento MEPLAN and UPLAN/SACMET simulations, the increase in travel speeds and decentralization of net activity location in the highway-oriented scenarios increase VMT and vehicle emissions. The increase in VMT ranges from two to ten percent and the increase in NOx (oxides of nitrogen) emissions ranges from 0.1 to nine percent. The scenarios that included combinations of LRT, auto-pricing policies, and land use measures produce reductions in VMT and emissions on the order of one to 14 percent. The reduction in VMT and emissions increases with the intensity of the policy or combination of policies in the scenario. In general, the scenarios that include Advanced LRT with VMT Pricing and/or land use measures provide the greatest reduction in VMT and emissions.

The analysis of costs and benefits with the results of the Sacramento MEPLAN model simulations indicates that the transit investment scenarios combined with land use policies may provide greater benefits (i.e., change in travel time and cost from the Base Case) than the highway-oriented scenarios. The UGB and Advanced LRT policy provides a change in total benefits that is more than double those in the Beltway scenario during the AM peak hour. The Advanced LRT scenario provides benefits that are greater than those in the HOV lane scenario, but not those in the Beltway scenario. The LRT only scenario and the scenarios that included the VMT pricing policy do not provide benefits as great as the highway-oriented scenarios. The costs and benefits included in the analysis do not include externalities and capital and O&M costs. Past research applying the cost and benefit measure to similar scenarios simulated with the SACMET model indicated that capital and O&M costs reduced benefits by a relatively small amount (Rodier et al., 2000).

In sum, when the scenarios in this case study, simulated with land use and transportation models that represent induced travel effects, are evaluated against four criteria, (1) congestion reduction, (2) emissions reduction, (3) protection of environmentally sensitive lands, and/or (4) total regional benefits, then the Advanced LRT with the UGB and/or the VMT pricing scenarios appear to outperform the other scenarios. However, if environmental benefits are weighted more heavily than congestion reduction in the evaluation, then the Advanced LRT and VMT pricing scenarios may also competitive alternatives to the highway-oriented scenarios.

Table 2. Percentage change in 2020 scenario results compared to the Base Case for the Sacramento MEPLAN and the UPLAN/SACMET model.

	Outer Ring[1] Households		Outer Ring Employment		VMT		Auto Speed (VHD)		NOx Emissions[2]		Total Benefit
	MEPLAN	UPLAN[1]	MEPLAN	UPLAN	MEPLAN	UPLAN	MEPLAN	UPLAN	MEPLAN	UPLAN	MEPLAN
HOV	1.0%	-0.01%	-4.2%	0.96%	4.3%[1]	2.1%	0.6%	2.1% (-4.9%)[2]	0.9%	3.3%	$1.35[3]
Beltway	1.2%		-4.6%		9.6%		2.5%		8.5%		$2.17
LRT	0.1%		-0.8%		-2.1%		0.8%		-2.0%		$1.15
Advanced LRT	0.3%	0.10%	-0.6%	-3.19%	-6.0%	-0.7%	3.5%	1.0% (-5.3%)	-5.7%	-0.9%	$1.68
VMT Pricing ($0.05 per mile)	0.0%	0.06%	0.0%	-0.81%	-10.0%	-0.7%	2.0%	0.2% (-2.1%)	-8.9%	-0.6%	$0.51
VMT Pricing ($0.02 per mile) + Advanced LRT	0.6%		-0.6%		-13.0%		3.7%		-12.0%		$0.33
Urban Reserve+ Infill + Advanced LRT	-0.9%		-1.8%		-8.8%		3.3%		-6.8%		$2.37
Urban Reserve + Infill + Advanced LRT + VMT Pricing ($0.01 per mile)	-0.7%		-1.4%		-12.9%		3.5%		-12.1%		$2.89
UGB + Advanced LRT	-8.1%	-8.31%	-6.8%	-8.67%	-10.2%	-2.3%	4.0%	1.7% (-10.3%)	-9.4%	-2.2%	$5.67
UGB + Advanced LRT + VMT Pricing ($0.01 per mile)	-7.9%	-8.28%	-6.6%	-9.55%	-13.7%	-2.9%	4.0%	2.0% (-12.4%)	-12.9%	-2.7%	$5.65

[1] The outer regional ring is the land outside the major urban/suburban areas in the region. [2] Emissions results are obtained from the DTIM2 and EMFAC 7F emissions models. [3] UPLAN refers to the UPLAN/SACMET model set.[4] Figures with percentage change from the Base Case scenario.
[5] Figures in parentheses are percentage change in VHD from the Base Case scenario. [6] Figures are per AM peak hour trip.
Note that shaded areas indicate that the scenario was not simulated with the UPLAN/SACMET Model

3. What is the relative significance of the results of the alternative scenarios simulated with the Sacramento MEPLAN model, given plausible errors in socio-economic projections?

Although there are many sources of uncertainty in projections from land use, travel, and emissions models (including specification, measurement, and calibration error) (Alonso, 1968), socioeconomic projections are considered to be some of the more important contributors (Harvey and Deakin, 1995; Rodier, 2004). These models rely in large part on projections of population, fuel prices, and incomes to generate future estimates of land uses, vehicle trips, VMT, and traffic volumes, which are then used in emissions models to make emissions projections. In this study, we conducted sensitivity analyses of plausible errors in population, fuel price, and income projections using the Sacramento MEPLAN model for the Base Case scenario (2020 time horizon).

Rodier and Johnston (2002) set confidence intervals on future Sacramento regional population projections by comparing past population projections with subsequent performances. Typically, the standard deviations of average projection error are used to set confidence intervals. To apply the method, we collected population projections of California counties from the California Department of Finance, historical county census counts, and intercensal county population estimates. Based on the analysis, a plausible standard deviation was estimated to be ± one percent for annual population growth projections.

Center for Continuing Study of the California Economy (CCSCE) is the only organization that projects household income at the regional and county levels for California (1997). All of their projections for the region were higher than those used by the Sacramento MEPLAN and the UPLAN/SACMET model. This study used CCSCE (1997) highest income projection in the sensitivity analysis (CCSCE, 1997).

The Energy Information Administration in its 2001 Annual Energy Outlook assembles available alternative forecasts of gasoline prices. The average annual increase in growth was forecasted to range from 0.2 to 0.9 percent. Gas prices are assumed to be constant in the Sacramento MEPLAN and the UPLAN/SACMET models and thus three high sensitivity scenarios were constructed (i.e., 0.2, 0.6, and 0.9 percent growth rates).

Using these plausible error ranges for future population, fuel price, and income projections, a sensitivity analysis was conducted using the Sacramento MEPLAN model. The results of the sensitivity analysis indicate the relative significance of alternative scenario projections examined above. For example, if plausible errors in socioeconomic projections indicates that the model's projections will vary by ± five percent for a 95 percent confidence interval, then only the results of alternative scenario simulations with the model that fall outside the ± five percent range would be considered significantly different from the Base Case alternative.

For acres of land consumed, levels of variation in total regional and sub-regional land consumption results were relatively large. The results for transportation investment and auto pricing scenarios typically fell within one standard deviation for the projections and thus there is a less than 68 percent chance that these alternatives may produce land use results that are significantly different from the Base Case. The scenarios that include the land use measures typically fell outside of two standard deviations and thus there is a greater than 95 percent chance that the land use results for those scenarios would be significantly different from the Base Case scenario.

Table 3. Percentage change in results in the 2020 sensitivity scenarios compared to the Base Case scenarios.

Sensitivity Scenarios	Acres of Land in the Outer Ring[1]	Total Acres of Land	VMT (daily)	Mean speed	NO_x Emissions[2] (daily)
Base Case	173,351	273,164	44.7 million	33 mph	55.1 tons
Population[3]					
Lowest (-2 s.d.)	-1.0%	-1.1%	-5.3%	1.8%	-5.3%
Low (-1 s.d.)	-0.5%	-0.6%	-2.5%	0.9%	-2.3%
High (+1 s.d.)	0.7%	0.7%	2.9%	0.0%	3.0%
Highest (+2 s.d.)	1.4%	1.5%	6.7%	-0.8%	6.8%
Household Income[4]					
High	3.3%	3.1%	3.1%	-1.3%	3.1%
Fuel Price[5]					
Low	0.0%	0.0%	-3.3%	2.1%	-6.9%
Moderate	0.0%	0.0%	-3.0%	2.3%	-7.0%
High	0.1%	0.0%	-6.1%	1.9%	-8.1%

[1] The outer regional ring is the land outside the major urban/suburban areas in the region. [2] Emissions results are obtained from the DTIM2 and EMFAC 7F emissions models.[3] Error levels for projected annual population growth rates for California Counties within two standard deviations (s.d.) from Rodier and Johnston, 2002. [4] The highest error level predicted by CCSCE, 1998. This was the only organization that predicted household income at the regional and county level for the Sacramento region. [5] Error levels for fuel price estimated by the EIA, 2001.

The level of variation produced from the population, income, and fuel price sensitivity scenarios for vehicle travel and emissions results were relatively moderate. They typically fell outside two standard deviations for the projections and thus there is a greater than 95 percent chance that that the results can be considered significantly different from the Base Case scenario. The exceptions are some of the more moderate transportation investment scenarios (i.e., the HOV and the LRT only scenarios). However, as described above limitations, in the MEPLAN model structure (i.e., sketch network and large zones) may tend to exaggerate the travel effects of the scenarios. Thus, it is unclear whether, if model error and error in socioeconomic projection used in the model were considered, these scenario results could be considered significantly different.

A similar sensitivity analysis was conducted with the SACMET model only (Rodier and Johnston, 2002). This study indicated that the results of all the scenarios simulated with the UPLAN/SACMET model would fall within one standard deviation for the population projections, and thus there is a greater than 68 percent chance the alternative scenarios may not be considered significantly different from the base case scenario. However, with respect to errors in income and fuel price projections, the results indicate that the scenarios simulated in this study may be significantly different from one another.

4. **Can auto-pricing policies be used to significantly reduce vehicle emissions without imposing losses on travelers?**

The Sacramento MEPLAN model is used to identify optimal levels of auto-pricing policies and optimal combinations of those policies with transit investment and land use measures. Optimal, in this study, is defined as meeting a fixed air quality sustainability constraint while minimizing costs or maximizing benefits to travelers. The air quality sustainability constraint is based on the uncertainty analysis described directly above and is a variation of the "No-Build Test" used in air quality conformity analysis. However, the objective in this analysis is improving, as opposed to not worsening, air quality. The air quality sustainability constraint uses the emissions results from the Base Case scenario (a low-build scenario, which includes only projects that would typically be included in a three-year TIP) simulated with population projections that represent the highest plausible level of population projection error (two standard deviations). This scenario produced the highest level of vehicle emissions of all the sensitivity scenarios. As discussed above, the results of an alternative scenario that produced emissions levels lower than those produced by this scenario cannot be considered significantly different from the Base Case (with a 95 percent confidence interval) and thus cannot be considered to significantly reduce vehicle emissions and improve air quality. If a pricing policy scenario meets the sustainability constraint, then the cost and benefit measure is employed to assess traveler effects by income group. The VMT pricing levels range from one to five cents per mile.

The results of this study with the Sacramento MEPLAN model suggest that relatively moderate VMT pricing policies with and without transit investment and land use measures can accomplish the objective of improving air quality without imposing losses on travelers, if total regional costs and benefits only are considered. However, if equity effects or cost and benefits by income groups are considered, then the answer is more complicated. The results of the analysis suggest that low-income groups incur losses in the scenario sets that include VMT pricing with and without Advanced LRT. Only when pricing policies are combined with the land use measures is the air quality sustainability constraint met, and relatively large benefits are obtained for all income groups. Similar finding have been obtained from scenario analyses with the SACMET model (Rodier et al., 2002; Rodier and Johnston, 1997). These results suggest that, with respect to auto-pricing policies, it may be particularly important to carefully assess the effect of the policies on a range of potentially disadvantaged groups and develop mechanisms to redress any potential losses to these groups (e.g., cash refunds or free shuttle transit services) (Rodier and Johnston, 1997).

Table 4. Results of the 2020 cost and benefit measure (per trip) from the Base Case to the VMT Pricing scenarios.

VMT Pricing	NOx Emissions	Low Income	Moderate Income	High Income	Total
+Base Case (+2 s.d. population projection)					
Lowest	-2.1%	-$0.11	-$0.39	-$2.51	-$1.07
Low	-4.0%	-$0.18	-$0.25	-$1.22	-$0.57
High	-7.0%	-$0.28	$0.01	$1.30	$0.40
Highest	-8.9%	-$0.37	$0.00	$1.68	$0.51
+Advanced LRT					
Lowest	-9.5%	-$0.02	$0.55	$0.11	$0.29
Low	-12.0%	-$0.09	$0.74	-$0.01	$0.33
High	-15.9%	-$0.25	$0.51	-$1.71	-$0.39
Highest	-19.1%	-$0.32	$0.71	-$1.55	-$0.26
+Reserve & Infill + Advanced LRT					
Lowest	-12.1%	$0.12	$1.81	$5.85	$2.89
Low	-15.3%	$0.00	$1.77	$5.70	$2.79
High	-18.7%	-$0.13	$1.71	$4.71	$2.40
Highest	-22.0%	-$0.19	$1.91	$5.04	$2.59
+UGB +Advanced LRT					
Lowest	-12.9%	$0.66	$4.03	$10.52	$5.65
Low	-15.3%	$0.51	$3.76	$8.91	$4.94
High	-19.9%	$0.35	$3.77	$9.35	$5.06
Highest	-22.8%	$0.22	$3.75	$9.71	$5.14

Notes: The Base Case uses the population projection with a +2 standard deviation. The VMT pricing scenario varies from one to five cents per mile. Figures are in 1990 dollars. Capital, O&M, and infill subsidy costs are not included in the benefit measure; some but not all of the additional monetary costs of the pricing policies are returned to travelers in the scenarios.

SUMMARY AND CONCLUSIONS

The following conclusions are made with respect to the four key motivating study questions:

1. **When applying the Sacramento MEPLAN model and the UPLAN/SACMET models to simulate the policy scenarios, what are the respective models' strengths and weaknesses, and what are the implications with respect to policy evaluation?**

The Sacramento MEPLAN model is a theoretically advanced an integrated land use and transportation model. It represents the regional economy and land market, redevelopment, and the effect of travel time and cost on the location of activities. Its representation of travel behavior and geography, however, is more aggregate than the representation in the UPLAN/SACMET model. This aggregation may tend to exaggerate traveler response to changes in travel time and cost introduced by alternative scenarios.

The UPLAN/SACMET model provides detailed representation of travel behavior and geography but lacks theoretical sophistication in its land use allocation model. Urban activities are influenced by changes in travel time and cost only; zoning would be consistent across scenario. This type of model is less costly to implement than a more sophisticated urban model. However, potential difficulties encountered in calibration may increase the cost of its implementation. Such a model could be very cost-effectively applied in conjunction with an expert panel to develop alternate land use scenario.

2. **Can transit investment, auto-pricing policies, and land use measures be just as, or more, effective in reducing congestion as highway alternatives and have the added benefit of improving air quality and protecting environmentally sensitive lands?**

The results of the scenario analysis with both models suggest that if land use measures are combined with increased transit and/or pricing policies, then these policies may be just as, or more, effective in reducing congestion as highway alternatives and have the added benefit of improving air quality and protecting environmentally sensitive lands. If the scenario evaluation placed somewhat greater weight on environmental protection than congestion reduction, then transit investment and pricing policies could also be favorably compared the highway alternatives.

3. **What is the relative significance of the results of the alternative scenarios simulated with the Sacramento MEPLAN model, given plausible errors in socio-economic projections?**

Given the plausible errors in socio-economic projections, the travel and emissions results for only the more moderate transportation investment scenarios (i.e., the HOV and LRT scenarios) would not fall outside the 95 percent confidence intervals for errors in projections. However, as just described, limitations in the Sacramento MEPLAN model structure may tend to exaggerate the travel effects of the scenarios. Thus, if both model error and socioeconomic projection error were considered in this uncertainty analysis, it is unclear whether the Sacramento MEPLAN scenario results could be considered significantly different from the base scenario.

A similar sensitivity analysis was conducted with the SACMET model only (Rodier and Johnston, 2002). The results of this study indicated that the results of all the scenarios simulated with the UPLAN/SACMET model in this study would not fall outside the 95 percent confidence intervals for errors in population projections and thus they may not be considered significantly different from the base case scenario. However, with respect to errors in income and fuel price projections, the results indicate that the scenarios simulated in this study may be significantly different from one another. A recent validation study of the SACMET model indicated that, over a ten-year period, approximately 50 percent of forecast error was due to model structure and 50 percent was due to uncertainty in socioeconomic projections (Rodier, 2004).

4. Can auto-pricing policies alone and/or in combination with other transit and land use policies significantly reduce vehicle emissions without imposing losses on travelers?

The results of this study with the Sacramento MEPLAN model suggest that this may only be true when pricing policies are combined with the land use measures. Similar finding have been obtained from scenario analyses with the SACMET model (Johnston and Rodier, 1999)**.** Pricing policies with and without transit investment resulted in losses to the lowest income group. These results suggest that the effect of pricing policies must be assessed on a range of potentially disadvantaged groups and mechanisms must be developed to redress any potential losses to these groups (Rodier and Johnston, 1998).

The results of this study highlight the critical importance of involving stakeholders in all phases of the transportation planning and analysis phase. First, stakeholder trust and cooperation in the planning process may be fostered by not using models that are biased in favor of highway alternatives (i.e., those that do not represent the land use and trip distribution effects of induced travel) and by making the uncertainty in the models explicit. Second, because of the large uncertainty in models, stakeholders must be involved in specifying the level of risk they will take to realizing the benefits proposed projects. For example, do stakeholders require only a five, ten, or twenty percent chance that the travel times and air quality benefits will not be realized by the project in order to make the financial investment in the project? Third, stakeholders must be involved in identifying the project alternatives, performance criteria, and the weights of the performance criteria. After all, transportation projects are funded by the community and are intended to benefit the community. Thus, plans must adequately reflect the values and goals of the community. Models can be used to help stakeholders think about the effects of different transportation investment choices, understand the trade-offs between the sometimes competing goals of congestion reduction and environmental preservation, and identify the guiding principles upon which they wish base the development of their community.

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