# Modeling Long-Range Transportation and Land Use Scenarios for the Sacramento Region, Using Citizen-Generated Policies

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**ABSTRACT**

The Sacramento, California region is engaged in an innovative long-range visioning process during 2004 and 2005, where the regional transportation planning agency is defining and modeling several 50-year growth scenarios. We worked with environmental and social equity citizens groups to define policies that would reduce emissions, serve lower-income travelers better, and preserve habitats and agricultural lands in the region. The citizens groups rejected the new freeways planned for the region, as well as the substantial freeway widenings for HOV lanes. In addition, they defined a more-ambitious transit system, involving new Bus Rapid Transit lines and shorter headways for all rail and bus service. This transit-only plan was modeled, by itself, and along with a land use policy for an urban growth boundary and a pricing policy for higher fuel taxes and parking charges for worktrips. We used a new version of the MEPLAN model to simulate these scenarios over 50 years and describe our findings regarding total travel, mode shares, congestion, emissions, land use changes, and economic welfare of travelers.

## INTRODUCTION

The ability of sophisticated urban and regional models to analyze policy alternatives is growing. As these models have improved, their use has been expanded (TMIP, 1998; Wegener, 1994). Presently, many large Metropolitan Planning Organizations (MPOs) and state departments of transportation are developing integrated land use and transportation models, for the first time. These agencies are responding both to local needs, expressed by their constituent cities and counties, and to external legal requirements, such as NEPA and the Clean Air Act air quality conformity modeling rule.

The Sacramento region has been a leader in developing urban models. In the fall of 2002 the Sacramento Area Council of Governments (SACOG) became one of the first MPOs in the United States to adopt a fully integrated land use and transportation model for policy purposes. This adoption was preceded by extensive model-demonstration exercises aimed at showing the usefulness of these models for urban and regional policy analysis. Researchers at the University of California, Davis, together with the consulting firms HBA Specto and Modelistica, implemented the first set of models with the cooperation of SACOG. These exercises were largely academic in nature. In 1998, the TRANUS model was implemented in the Sacramento region (Johnston and de la Barra, 2000). Two versions of MEPLAN followed and have been used in several academic policy studies (for example: Rodier, et al., 2002, and Abraham and Hunt, 1999).

The purpose of this report is to present results from policy scenarios run with the third installment of the MEPLAN model in the Sacramento region. These policy scenarios were design
ed via outreach work with two Sacramento-based citizens groups: the Environmental Council of Sacramento (ECOS) and Sacramentans for Transportation Equity (SAC-TE). It was anticipated

that by giving these citizens groups access to the model, a greater diversity of policies would be evaluated and greater weight would be given to their positions.

**IMPROVEMENTS FROM SAC-MEPLAN2 TO SAC-MEPLAN3**

In our past research, we used a four-county (El Dorado, Placer, Sacramento, and Yolo counties) version of MEPLAN with a 1990 base year. The current model being used for this report, SAC-MEPLAN3, is not a research model but was funded by SACOG. This model contains all six counties (adds Yuba and Sutter counties) in the SACOG region. It represents the full travel network (14,558 links v. 2,124 in earlier versions) and has better input data. Earlier versions ran in 5-year time steps, while this version runs in 2.5-year steps. This enhances convergence in the land and travel markets. The calibration of this model was done for a base year of 2000 and was closely scrutinized by SACOG staff and the authors of this report.

This version was also calibrated on more accurate floorspace rent data than were the earlier two versions. Johnston re-interviewed real estate experts in the region and read private reports from leasing firms on rents for industrial, office, and apartment properties. These data were assembled for display in a geographic information system and a one-day meeting of real estate experts was held at the SACOG offices. This process seemed to work well, as it resulted in a greater range of average zonal rent values for each activity type and a better grasp of zones that were dilapidated and which were in high demand.

The MEPLAN modeling framework is described in Hunt and Simmonds (1993). The basis of the framework is the interaction between two parallel markets, a land market and a transportation market. Behavior in these two markets is a response to price, and price-like signals that arise from market mechanisms. In the land markets, floorspace price and generalized cost of travel (disutility) affect production, consumption, and location decisions by activities. In the transportation markets, money and time costs of travel affect both mode and route selection decisions. The following description is an abbreviated version of what can be found in Johnston, et al. (2001).

The framework is moved through time in steps from one time period to the next, making it “quasi-dynamic” (Meyer and Miller, 1984). In a given time period, the land market model is run first, followed by the transportation market model, and then an incremental model simulates changes in the next time period. The transportation costs arising in one period are fed into the land market model in the next time period, thereby introducing lags in the location response to transport conditions. See Hunt (1994) or Hunt and Echenique (1993) for descriptions of the mathematical forms used in MEPLAN and Rodier, Johnston, and Abraham (2002) for a more complete explanation of the model structure.

## ANALYSIS METHODS

### Citizen Outreach

Frequent meetings were held during the Fall of 2003 and Winter of 2004 with ECOS, the umbrella council of environmental groups, and SAC-TE, the transportation equity group. In the initial meetings, an overview of the MEPLAN model was provided to the groups as well as an outline for this project. These meetings produced two important outcomes. First, a set of maps was produced with new transit lines (regionwide Bus Rapid Transit, for example). Second, an urban growth boundary was decided on, along with higher density infill.

### The Base Case

All scenarios used virtually the same internal populations in the various model years: about 1.9 million in 2000, 2.7 million in 2025, and 3.6 million in 2050. Inter-regional shifts in households and firms is represented in the model, but these shifts were less than 1% across the scenarios. Household size is projected to fall from 2.66 to 2.36, and so household formation will be more rapid than population growth. This is a fairly rapidly growing region with prime ag lands in Sutter, Yolo, and Sacramento counties and with important Sierra foothill habitats in Yuba, Placer, and El Dorado counties. The region is in air quality nonconformity for ozone and particulates.

The Base Case represents a relatively unconstrained land use scenario. In 2000, over 800,000 vacant acres are zoned for development. By 2050 only roughly 250,000 of these have been developed (leaving more than a half million vacant acres zoned for development). This allows households and employment to locate wherever they want. This land use scenario was derived from the local general plans of the cities and counties in this region. The travel networks consist of the current network (as it was in 2000) with incremental additions in the years 2005, 2015, 2025, 2035, and 2050. These travel networks were obtained directly from the travel demand model currently being employed by SACOG. Below is an abbreviated description of the major network improvements.

There are two notable projects, as they are new freeways or expressways: the southeast bypass in Sacramento County, connecting SR99 and I-5 in the South with SR50 in the East, and the Placer Parkway, which is a northern ring road in Placer County. Together, these two new highways consist of a beltway around most of the circumference of the central urban area (S, E, and N). Other major road projects include new HOV lanes on all radial freeways, along with 25 new HOV ramp bypasses and three new interchanges. In addition, several highway bypasses are built around the cities in the northern counties. In total, 166 (one-way) lane-miles of general freeway/expressway are added, along with 251 lane-miles of HOV lanes, and 56 on- and off-ramps are built or widened.

Major transit improvements completed by 2050 include 29 new bus lines, 10 new Light Rail Transit (LRT) lines, and 5 new Bus Rapid Transit (BRT) lines.

**Policy Scenarios**

The citizens groups felt strongly that transit options needed to be improved and that air quality issues and the rapid conversion of undeveloped land to urban uses needed to be addressed. To do this, several strategies were adopted: 1. limit roadway expansions, including HOV lane additions, 2. dramatically improve transit service, 3. use a strict urban growth boundary while promoting infill development, and 4. introduce worktrip parking charges and higher fuel taxes.

*Scenario 1: Transit Improvements*

Scenario 1 consists of massive improvements to the transit facilities in the region. All road projects beyond 2005, including HOV lanes, were canceled (virtually all the ones listed in the Base Case). Fifteen new BRT lines were added and 4 of the 5 BRT lines from the Base Case were carried over as well. For roadways with three or four lanes in one direction, a lane was taken and dedicated as a BRT lane. On roadway sections with only two lanes, a BRT lane was added. BRT lines were given headways of 20 minutes. In total, we added 502 (one-way) miles of BRT lines. This total is high because the lines go to all the outlying cities. These long lines will be low in cost, as they are in dedicated lanes, but on surface streets with no grade separations.

In 2015, LRT and bus headways remain the same as in the Base Case, ranging from 10 to 90 minutes. Link speeds for LRT range from 6 miles per hour to 47 miles per hour in the Base Case. These are increased to a minimum of 30 miles per hour for all LRT and BRT links. This would require grade separation of LRT (underground) in the downtown zones and separate lanes for BRT in urban areas. In 2025, headways for LRT, BRT, and standard buses were cut by 50%. Note that a drop in headways requires additional transit vehicles, a major capital expenditure.

In 2035, the headways of LRT, BRT, and standard buses were all set to 7.5 minutes. Overall, we attempted to create a transit-only scenario with roughly the same capital costs as the Base Case, to make the comparison easier and fair.

*Scenario 2: Urban Growth Boundary*

Scenario 2 utilized the Base Case networks, including all roadway improvements and adds a tight urban growth boundary. The massive capital improvements of the Base Case travel networks improve travel accessibility in nearly every zone. This increased accessibility means that people and jobs can move farther from the CBD without incurring increased travel costs. In order to prevent this, an urban growth boundary was implemented by restricting the amount of land available for development in the outer zones. In total, over 480,000 acres of developable land were removed from the rural zones. This still left plenty of developable land within the urban growth boundary. At the conclusion of model year 2050 there was still land available in every category within the UGB.

In order to make this project comparable with the work that SACOG has undertaken in the Sacramento Area Blueprint visioning project, the UGB was designed to replicate SACOG's most growth-controlled scenario. It should be noted, however, that while SACOG's scenario does allow small amounts of growth in the more rural parts of the region, the UGB modeled here does not.

*Scenario 3: Transit Improvements with Urban Growth Boundary*

Scenario 3 utilized the networks created for Scenario 1 (transit improvement scenario) and added the tight urban growth boundary created for Scenario 2. The massive transit improvements of Scenario 1 improve travel accessibility within the zones affected by the creation of these new, high-capacity, high-speed transit modes. The transit improvements may facilitate some sprawl growth, although in different patterns from the Base Case, in the outer zones. In order to combat this, the urban growth boundary created for Scenario 2 was modeled in tandem with the travel networks of Scenario 1.

*Scenario 4: Transit Improvements with Pricing*

In this scenario, the Scenario 1 networks were used in combination with a gas tax and a parking charge, in constant dollars, in all years. The parking charge was applied at the destination of work trips only, in the amounts of $6.00 per trip in the central business district (CBD) and $2.00 per trip everywhere else. The gas tax was $1.00 per gallon above the 2000 price and was applied to all automobile trips. This is a modest price increase, over 50 years, given that most experts predict a substantial real price increase by 2020.

*Scenario 5: Transit Improvements with Pricing and the Urban Growth Boundary*

In scenario 5 we combined the previous three scenarios to create a scenario with improved transit service, parking prices with an increased gasoline tax, and the urban growth boundary. Our past work has shown this to be the most effective scenario in reducing travel and emissions. We wanted to see how it would perform under severe road congestion, over 50 years.

We describe the methods used to calculate the various results in with the discussion of the results, so the methods will be clearly related to the results obtained.

## RESULTS

It should be noted that for the Base Case and all scenario runs reported here the population and employment totals remained nearly constant. MEPLAN allows additional households and firms to enter or leave the region if market conditions, relative to outside zones warrant it, typically in relatively small amounts. Also, efforts were made to maintain the Base Case assumptions in each scenario except for the policy changes noted in the description of each scenario, above. The MEPLAN travel model only includes travel for the a.m. peak (3-hour) period and so we are not accounting for all daily trips. In addition, worktrips are a high proportion of modeled trips.

**Travel Changes**

*Base Case v. Scenario 1: Transit Improvements*

First, note that overall transit share falls in 2050, compared to 2025, in the Base Case itself. This is due to limited transit coverage and increasing sprawl, where more households locate beyond transit service.

As can be seen in Tables 1 and 2, halting road expansions while dramatically improving transit service in Scenario 1 lowers vehicle miles of travel (VMT) in 2025 and 2050, compared to the Base Case. Mode shares also change as more households choose to take transit and fewer are driving.

*Base Case v. Scenario 2: Urban Growth Boundary*

The UGB scenario is different from the others considered here. While transit improvements and pricing strategies entice people to move closer-in or switch from auto to non-auto modes, the UGB scenario is a regulatory action that does not allow development in certain zones. Sacramento County already has an urban services boundary, but the UGB modeled here is stronger and extends to all six counties.

The UGB has the strongest effect on the location decisions of households and firms (see Tables 3 and 4). It also results in travelers choosing transit, although not quite as strongly as the transit scenario (Tables 1 and 2). Given that this scenario has all of the road improvements of the Base Case, it provides a strong argument for the importance of land use planning as a tool to reduce VMT and improve transit's viability. In contrast to Scenario 1, which utilized massive capital expenditures in transit to bring about land use and travel changes, the creation of a UGB is a low-cost alternative, which local governments may find appealing. Scenario 2 is similar to SACOG's most-compact scenario from their Regional Blueprint visioning process, underway in 2004, and so we can see that Scenario 1 reduces VMT more, especially in 2050.

*Base Case v. Scenario 3: Transit and Urban Growth Boundary*

The combination of transit improvements and a UGB reduce VMT by roughly 15% by 2025 and roughly 20% by 2050. Not surprisingly, this combination also produces strong downward shifts in the mode share of single- and high-occupant vehicles while improving the mode shares of transit, walk, and bike. This scenario is clearly better in reducing travel than Scenario 2, which is very close to the scenario adopted by SACOG in its 50-year visioning process in 2004.

*Base Case v. Scenario 4: Transit and Pricing*

As can be seen in Tables 1 and 2, while the VMT impacts are similar to Scenario 3, the shifts in mode to transit are more pronounced. The utility of driving an auto is directly tied to its costs. This scenario raises the costs of driving significantly. Tables 3 and 4 show that location changes are not as large as those caused by the UGB scenario. This suggests that a moderate market-based solution such as these parking charges and gasoline taxes, may have similar VMT, and even better mode share impacts than a regulatory policy such as a UGB. Readers should note, however, that the UGB will reduce growth in the outer zones more than the pricing scenario. So, it may be more appealing in terms of impacts on habitats and agricultural lands. The peak-period travel model in MEPLAN has a high proportion of worktrips, which are affected by the parking charges. Daily mode shares and VMT would not be affected as much.

*Base Case v. Scenario 5: Transit, UGB, and Pricing*

By far the largest reduction in VMT and the greatest shifts away from automobile modes occurs when all three environmental and equity policies are modeled together. Tables 1, 2, and 3, 4 demonstrate fairly substantial changes in travel and location decisions. In response to these policies, households and employment are moving closer to the urban core and travelers are choosing to take transit, walk, and bicycle modes in greater numbers. We expect synergism among these policies, as transit has high service levels and so can handle the travelers priced out of cars. Again, the parking pricing will have strong effects, because of the peak period travel being modeled.

Looking at all of the policy scenarios, travel changes were larger in 2050 than in 2025, as some transit improvements occur in 2035. Also, there is more time for transit and the other policies to affect land development and locators. The scenarios were ranked in a reasonable fashion, according to theory and compared with previous simulations by us and by others. In addition, the changes in development across zones seem broadly reasonable, given what we know about this region's land markets. All elasticities for travel behaviors were within acceptable ranges, in terms of total travel and mode choices. We only report here on a small number of the model's outputs. Floorspace rents, for example, also were reasonable, as well as travel times.

## Congestion

We defined congestion as those links with a volume/capacity ratio of 1.00 or greater (generally, level-of-service E/F). Due to the complexity of the network and the software, we only calculated congestion on freeway and expressway links. We assume that congestion on the other roads correlates strongly with freeway/expressway congestion, due to the assignment model being capacity-restrained and equilibrated to convergence and the whole model set also being equilibrated. This version of MEPLAN uses an a.m. peak model, so this is the most-congested period.

Anyone can make a model produce less VMT with various policies. The truly interesting issue is whether one can do this without worsening congestion. In theory, we expect the pricing scenarios to reduce congestion, due to the higher cost of travel and parking. In fact, these two scenarios have the lowest lane-miles of congestion in 2025. They also have the highest increases in speed of all scenarios (along with HOVs in Scenario 2), in 2025. It is very significant to also note that all the other scenarios decrease congestion or keep it the same in 2025. All scenarios also have higher average auto speeds than the Base Case in 2025, except Scenario 1. The poorer performance of Scenario 1 is probably due to the reduced freeway lane-miles and transit not having short enough headways yet, in 2025.

Conditions are more complex in 2050. All scenarios have higher congestion levels than in 2025 and all have roughly the same congestion levels (probably within the error range of the model). This is due to the freeways leading into the CBD all being saturated and more traffic now being shunted to surface streets, which we are not measuring here. The slightly higher congestion in Scenario 1 is probably due to the increase in CBD employment in this scenario. Scenarios 3 and 5 have congestion levels about the same as the Base Case, also probably due to the increases in CBD employment. All scenarios increase average auto speeds, compared to the Base Case, except Scenario 1, as occured in 2025. Scenarios 4 and 5 have the highest average speed for autos.

**Emissions Changes**

Due to limited resources, we did not run the California emissions model. We have discovered in our past studies, using earlier versions of this urban model and using the SACOG travel model, however, that emissions are very strongly correlated with VMT and the percentage differences from the Base Case are very close to the percentage differences in VMT (Johnston and Rodier, 1999). So, the emissions reductions here will be very similar to the VMT reductions. Daily emissions rankings would likely be the same as the rankings for the a.m. peak period. Percentage differences from the Base Case would also be similar.

This region may have difficulty showing conformity in the next Metropolitan Transportation Plan, due to the recently adopted State emissions inventory with more SUVs in this region's current and future vehicle fleets and due to increases in most types of emissions for the higher vehicle speed classes. There is considerable political pressure in this region to reduce VMT and emissions in the future.

In this study, as in our past ones, we find that transit, by itself, is only moderately effective in reducing VMT and emissions. Transit needs to be supported by land use policies, or by pricing policies, to be really effective.

**Location Changes**

The key advantage of using MEPLAN over a traditional travel demand model is that households and employment can change location in response to changes in the travel conditions. In our past work, we have shown that an urban model more strongly differentiates among scenarios than does a travel model, due to these synergistic land use effects (Rodier, Johnston, and Abraham, 2002). The scenarios run in this study produced significant shifts in the location of households and employment.

In order to facilitate the presentation of the land use shifts, the 71 internal zones used by the MEPLAN model were grouped into three superzones. The zone comprising the CBD of Sacramento City was left alone due to its unique density, land use mix, and accessibility by freeway and transit. Next, all of the zones that comprise the bulk of the current urban development in the region were grouped into a second superzone (Urban/Suburban). These two groups include all the zones that are within the UGB created for Scenarios 2 and 3. The final zone, the Rural Zone, is comprised of the zones with limited, scattered rural development. The shifts of employment and population by these superzones are shown in Tables 3 and 4.

The UGB accounts for the largest location changes. Employment and households shifting from the Rural Zone to the Urban/Suburban and CBD superzones make transit more accessible to a greater percentage of the total population. The CBD loses employment in Scenario 1 in 2025, compared to the Base Case, because we reduced radial freeway capacity to the CBD and the transit system is complete but does not yet have short headways. In Scenario 4, the CBD loses employment in 2025 because of the higher worktrip parking charge in this zone ($6 v. $2 elsewhere). The CBD gains employment in all scenarios in 2050, due to the freeways being more congested throughout the region and transit having short headways and serving the CBD well.

Note that the transit scenario (1) reduces households and employment in the outer ring less than 1% and the transit plus pricing scenario (4) reduces them 1-4% in 2025. In 2050, these losses in the outer ring are a few percent, due to the higher road congestion and better transit service in the CBD and Urban/Suburban zones.

**Economic Benefits for Travelers**

Because the use of economic indicators is not common in the U.S., we discuss the methods issues in some detail.

We calculated changes in private traveler economic welfare, using the compensating variation (CV) measure. Small and Rosen (1981) show that the disutility log sums from a logit mode choice model can be used to obtain economic welfare measures for travelers. See Rodier and Johnston (1998) for a description of this method, as applied to the SACOG travel model. In MEPLAN, this indicator was obtained by multiplying the disutilities (log sums by flow type) for all trips (all origin/destination pairs) from the mode split model by the flow volumes for each flow type for all trips. The log sums take into account all costs of travel (time and money). Basically, this measure is similar to consumer surplus, meaning it measures the benefits for the consumer (of travel) above what they are willing to pay, sometimes called net benefits. Consumer surplus is widely used by agencies throughout the world for the evaluation of public projects of all sorts.

We give benefits separately for three traveler income classes for the worktrip in 2050 (Tables 5 and 6). This allows the understanding of vertical equity (equity by income class) for our scenarios. The benefits for the nonwork trips probably have the same signs as the benefits for the worktrips, so we believe that one can use this measure as a surrogate for overall traveler equity for the a.m. peak period. For all other trip purposes, we can only get the measure for all travelers together, so we give a total benefit for all personal trips. This measure is then the indicator for aggregate traveler economic welfare in the scenario. All economic measures are the difference of the policy scenario minus the Base Case, for the 3-hour a.m. peak-period value (for an average weekday), including about 1.9 million trips. From past experience, we believe that the daily welfare measures would rank the same, but would be 3-4 times as great for aggregate welfare. Per trip welfare would be somewhat smaller, due to lower congestion and time costs in the off-peak periods.

The better measure of economic welfare in an urban model would be locator surplus, but this measure in MEPLAN is not theoretically sound, so we don't use it. Locator welfare captures changes in household and firm welfare in consuming space and includes changes in traveler welfare in the design of the indicator. There may be cases where the traveler experiences an increase in traveler welfare but a loss in overall, locator, welfare. Our UGB scenarios may fall into this category, because some middle- and upper-income households cannot consume space in the outer zones and, instead have to locate in the middle ring. So, they lose locator welfare but gain traveler welfare through shorter trips. The number of such households is relatively small, however. If one takes the moral position that we want a UGB regardless of effects on locator surplus, then we don't care about these losses. If habitat protection were critical in the region, you could take this view. In the obverse, there may be situations where travelers experience a loss of traveler welfare but a gain in locator welfare. This could occur in the Base Case and in Scenario 1 where sprawl is permitted and some households locate on cheap land in the outer ring, experiencing higher locator welfare, but have higher travel costs. Again, the number of such households is relatively small, about 20% of the region's households.

We also note that our results are expressed with none of the fuel taxes refunded in the region. Many proposals for higher fuel taxes include a refund that does not affect travel, often in the form of lower regional sales taxes. If the higher fuel tax revenues were refunded via lower sales taxes, this would be a very progressive redistribution and so the low-income households' welfare would improve greatly. The welfare of the middle- and high-income travelers would also improve, perhaps making their welfare become neutral in Scenarios 1, 4, and 5, which would make overall welfare become roughly neutral also.

The parking charges for worktrips would very likely be refunded in the form of higher salaries and wages, as the owners of the parking structures would no longer be paid by the employers. Generally, we expect the labor market to compensate workers with equivalent wage increases. If we accounted for this change in salaries, which is quite complex, all of the welfare indicators would be higher, probably making all of them become positive. In past studies using the SACOG travel model, we found that similar pricing, transit, and transit with pricing scenarios had positive benefits for all income classes, after refunding the new fuel taxes and parking charges (Rodier and Johnston, 1998).

Another issue is that we did not deduct the capital and operation costs for each scenario in the analysis. One can do the calculation without this, by saying that you are simply doing a private, or users's, welfare analysis. We can also say that we are comparing scenarios with similar costs, and so they don't affect the analysis rankings much. Or one can do a more complete public welfare analysis and include the project capital and operation costs. Usually, these costs are small, compared to the users' costs in the system, because the capital costs are spread over many years. In two papers (Johnston and Rodier, 1998; Johnston and Rodier, 1999), where we were evaluating various similar transit, UGB, and pricing scenarios in this region for 30 years, we found that these project costs were small and did not affect the welfare results significantly, absolutely or ordinally.

The traveler welfare measure that we used, however, is a more comprehensive measure of congestion than are the road congestion and auto speed measures, above. They both omit the 20-30% of trips that are not in autos. The traveler welfare measure captures all trips by all modes, by congestion levels at the time of travel, using the time costs appropriate to each traveler. This measure is used in many developed and developing nations in transportation plan evaluation.

Table 5 gives the aggregate welfare changes and we see that the three UGB scenarios (2, 3, 5) have positive benefits for the region's economy, due to shorter trips. The daily welfare change would be about 3-4 times as great, quite significant sums ($300-600 million/year for weekdays alone, nearly as large as the Federal and State transportation budget of the region). One may think of about a third of these benefits (cost savings) as increases in the disposable income of the households. One expects that most of these savings would be spent in the regional economy. The rest of the savings are time savings, which would be spent on other activities. As mentioned above, if the fuel taxes and parking charges were refunded, Scenario 4 would likely be positive overall or neutral. All scenarios are positive for the low-income households, however, even without refunds, due to the very strong transit improvements. Many observers believe that equity is the most pressing problem in U.S. transportation systems, as sprawling employment and the suburban exclusion of apartments make travel to work, shopping, and services difficult for many central city low-income households.

Table 5 gives the same data in terms of benefits per trip, a more intuitive unit. The signs and sizes of these indicators are similar to those from our past studies using the SACOG travel model. Please note that the benefits are higher for the middle-income and high-income travelers because time costs are calculated as a percentage of income and also there are more households in these categories. <u>So, overall, the economic benefits to travelers in the region of a UGB policy are very large and a strong transit policy greatly benefits the low-income travelers.</u> Also, we note that in Scenario 5, the added UGB policy makes aggregate benefits become strongly positive for the region, even though pricing is included and the revenues are not refunded. This finding corroborates the prevalent wisdom of the Smart Growth advocates, that we need better transit, infill with UGBs, and the pricing of auto travel.

Table 6 adjusts the aggregate welfare measure for 2050 by adding in the full costs of owning a car. The new car cost is 56 cents/mile (AAA web site, 7/28/04), so we estimate the full cost for all cars at 45 cents/mile. Since we have already accounted for the out-of-pocket costs of 15 cents/mile, we added in a 30 cents/mile cost by multiplying it by the VMT for each scenario. This, then, gives the more-inclusive and theoretically more correct full-cost traveler welfare measure. See our earlier papers, cited above, for a discussion of this issue. Basically, in long-term modeling, we believe that auto ownership decisions are taken into account, especially in an urban model where household locations change and where workers and jobs are linked according to economic flows. Because there is some debate about this, we do the calculation both ways. We can only do this for all personal trips, since we can't get VMT for worktrips by income group in MEPLAN. This cost is not the actual full cost of auto ownership, since it excludes garaging and various government subsidies. It also excludes external costs.

It appears that, with our conservative full user cost method, all scenarios are strongly beneficial, except for Scenario 1, which is slightly negative, economically. This scenario, however, will still be very positive for the lower-income households, as all income classes will benefit more in this calculation, compared to Table 5. Again, with this method, the UGB scenarios have even more strongly positive effects on travelers, due to shorter trips.

## CONCLUSIONS

This study has demonstrated several important points. First, integrated land use and transportation models can be used in an outreach setting among citizens of varying levels of technical expertise and these citizens can understand roughly how the model works and which policy inputs are important. Second, a model such as MEPLAN can produce broadly reasonable rankings for a variety of policy scenarios 50 years into the future. The policies tested here are likely to be of interest to a broad array of planners, engineers, business groups, elected officials, and citizens concerned about congestion, air pollution, and urban sprawl. In another paper, we have outlined the importance of such long-range visioning and recommended a suite of modeling tools (Johnston and Garry, 2003).

In terms of the policies analyzed, Scenario 5 is the best in terms of lower emissions. Scenarios 2, 3, and 5 were best for full-cost traveler welfare. Scenarios 3, 4, and 5 are the only ones that reduce VMT and emissions more than 10% in 2025. Scenarios 1-5 all have positive economic effects on low-income travelers, mainly due to improved transit services. These results are similar to those from our earlier studies using previous versions of this model (Rodier, Johnston, and Abraham, 2002) and broadly similar to those using two other urban models (Hunt et al., 2001).

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**TABLE 1 Travel Outputs for the Year 2025 by Scenario**

| | Base Case | Scenario 1: Transit Improve-ment | Scenario 2: UGB | Scenario 3: Transit with UGB | Scenario 4: Transit with Pricing | Scenario 5: Transit with UGB and Pricing |
|---|---|---|---|---|---|---|
| Total VMT | 9,382,970 | 8,657,667 | 8,688,085 | 8,001,591 | 8,074,981 | 7,501,583 |
| % Change from Base Case | | -7.73% | -7.41% | -14.72% | -13.94% | -20.05% |
| % of Lane Miles Congested | 32.25% | 30.85% | 29.60% | 30.30% | 27.17% | 26.55% |
| | | | | | | |
| % Changes in Ave. Travel Speed from Base | | | | | | |
| All trips: | | | | | | |
| Single occupant vehicles | (16.5 mph) | -3.98% | 1.95% | 0.29% | 6.59% | 11.00% |
| High occupant vehicles | (19.6 mph) | -2.83% | 3.50% | 0.78% | 4.55% | 8.14% |
| | | | | | | |
| Work trips: | | | | | | |
| Single occupant vehicles | (15.7 mph) | -6.71% | 3.35% | -0.33% | 5.36% | 16.55% |
| High occupant vehicles | (18.1 mph) | -5.81% | 9.61% | 2.46% | 3.61% | 20.93% |
| | | | | | | |
| *Mode Share Overall:* | | | | | | |
| WALK | 7.77 | 7.98 | 9.91 | 10.03 | 8.98 | 11.08 |
| Single Occupant Vehilces | 38.56 | 36.50 | 37.14 | 35.73 | 29.87 | 28.67 |
| TRANSIT | 5.24 | 9.50 | 5.90 | 9.58 | 11.31 | 12.10 |
| High Occupant Vehicles | 43.37 | 40.68 | 41.57 | 39.12 | 41.77 | 40.14 |
| BIKE | 5.08 | 5.34 | 5.48 | 5.53 | 8.07 | 8.03 |
| | | | | | | |
| *Mode Share for Work Trips:* | | | | | | |
| WALK | 3.23 | 3.31 | 4.88 | 4.91 | 10.52 | 13.85 |
| Single Occupant Vehilces | 75.36 | 70.31 | 71.59 | 67.97 | 39.79 | 35.36 |
| TRANSIT | 6.83 | 11.61 | 8.14 | 12.38 | 23.71 | 25.54 |
| High Occupant Vehicles | 9.67 | 8.98 | 9.01 | 8.17 | 6.38 | 5.55 |
| BIKE | 4.90 | 5.79 | 6.38 | 6.57 | 19.60 | 19.70 |

**TABLE 2 Travel Outputs for the Year 2050 by Scenario**

| | Base Case | Scenario 1: Transit Improve-ment | Scenario 2: UGB | Scenario 3: Transit with UGB | Scenario 4: Transit with Pricing | Scenario 5: Transit with UGB and Pricing |
|---|---|---|---|---|---|---|
| Total VMT | 11,494,649 | 10,138,264 | 10,597,944 | 9,199,837 | 9,438,641 | 8,649,975 |
| % Change from Base Case | | -11.80% | -7.80% | -19.96% | -17.89% | -24.75% |
| % of Lane Miles Congested | 36.36% | 38.66% | 34.95% | 36.69% | 35.28% | 36.14% |
| | | | | | | |
| % Changes in Ave. Travel Speed from Base | | | | | | |
| All trips: | | | | | | |
| Single occupant vehicles | (13.5 mph) | -2.07% | 2.43% | 1.95% | 10.29% | 13.56% |
| High occupant vehicles | (16.4 mph) | -3.04% | 2.44% | 1.49% | 3.64% | 7.73% |
| | | | | | | |
| Work trips: | | | | | | |
| Single occupant vehicles | (12.5 mph) | -4.29% | 3.80% | 1.69% | 12.49% | 21.87% |
| High occupant vehicles | (14.7 mph) | -3.44% | 7.71% | 4.14% | 11.14% | 20.32% |
| | | | | | | |
| *Mode Share Overall:* | | | | | | |
| WALK | 9.36 | 9.00 | 13.33 | 12.83 | 9.61 | 13.27 |
| Single Occupant Vehilces | 36.53 | 32.36 | 33.95 | 30.61 | 26.70 | 24.41 |
| TRANSIT | 4.82 | 13.38 | 5.52 | 13.59 | 14.73 | 16.30 |
| High Occupant Vehicles | 42.15 | 37.31 | 39.35 | 35.08 | 38.78 | 36.25 |
| BIKE | 7.14 | 7.95 | 7.85 | 7.89 | 10.19 | 9.76 |
| | | | | | | |
| *Mode Share for Work Trips:* | | | | | | |
| WALK | 4.37 | 4.16 | 7.51 | 7.23 | 10.20 | 14.71 |
| Single Occupant Vehilces | 71.10 | 62.00 | 64.73 | 57.38 | 32.47 | 26.71 |
| TRANSIT | 6.87 | 14.43 | 8.48 | 16.20 | 26.34 | 30.21 |
| High Occupant Vehicles | 8.74 | 7.70 | 7.88 | 7.07 | 5.00 | 4.17 |
| BIKE | 8.91 | 11.72 | 11.39 | 12.13 | 25.98 | 24.19 |

**TABLE 3 Shifts in Location of Households and Employment for 2025**

| | Scenario 1: Transit Improvement | Scenario 2: UGB | Scenario 3: Transit with UGB | Scenario 4: Transit with Pricing | Scenario 5: Transit with UGB and Pricing |
|---|---|---|---|---|---|
| % Change in the Number of Households from the Base Case | | | | | |
| CBD | 0.04% | 7.06% | 6.88% | 2.36% | 9.04% |
| Urban/Suburban | 0.12% | 20.09% | 20.07% | 1.18% | 20.09% |
| Rural | -0.44% | -69.00% | -68.98% | -4.30% | -69.37% |
| % Change in the Number of Employees from the Base Case | | | | | |
| CBD | -0.61% | 4.04% | 3.52% | -1.10% | 2.95% |
| Urban/Suburban | 0.15% | 8.55% | 8.60% | 0.26% | 8.66% |
| Rural | -0.64% | -62.92% | -62.99% | -1.04% | -63.03% |

**TABLE 4 Shifts in Location of Households and Employment for 2050**

| | Scenario 1: Transit Improvement | Scenario 2: UGB | Scenario 3: Transit with UGB | Scenario 4: Transit with Pricing | Scenario 5: Transit with UGB and Pricing |
|---|---|---|---|---|---|
| % Change in the Number of Households from the Base Case | | | | | |
| CBD | 1.06% | 8.84% | 9.45% | 3.64% | 11.60% |
| Urban/Suburban | 1.08% | 29.05% | 29.02% | 2.66% | 29.07% |
| Rural | -3.00% | -79.23% | -79.21% | -7.38% | -79.41% |
| | | | | | |
| % Change in the Number of Employees from the Base Case | | | | | |
| CBD | 3.62% | 5.46% | 8.66% | 3.23% | 8.22% |
| Urban/Suburban | 0.55% | 13.68% | 13.45% | 0.68% | 13.49% |
| Rural | -4.98% | -76.01% | -76.61% | -5.40% | -76.52% |

**TABLE 5 Total and Per Trip Changes, from the Base Case, in Private Economic Benefits (in 2000 Dollars) to Commuters by Income Class and to All Non-commercial Travelers in 2050**

| | **Scenario 1: Transit Improvement** | **Scenario 2: UGB** | **Scenario 3: Transit with UGB** | **Scenario 4: Transit with Pricing** | **Scenario 5: Transit with UGB and Pricing** |
|---|---|---|---|---|---|
| Low income commuters | $4,002.00 | $67,240.00 | $68,597.00 | $16,722.00 | $36,898.00 |
| | $0.05 | $0.89 | $0.91 | $0.22 | $0.49 |
| Medium income commuters | -$57,270.00 | $154,090.00 | $124,474.00 | -$128,641.00 | $69,617.00 |
| | -$0.29 | $0.79 | $0.64 | -$0.66 | $0.36 |
| High income commuters | -$20,453.00 | $92,170.00 | $60,147.00 | -$159,262.00 | -$49,140.00 |
| | -$0.14 | $0.65 | $0.42 | -$1.12 | -$0.35 |
| All non-commercial trips | -$455,377.00 | $811,270.00 | $489,274.00 | -$305,614.00 | $429,009.00 |
| | -$0.24 | $0.44 | $0.26 | -$0.16 | $0.23 |

**TABLE 6 Total and Per Trip Changes, from the Base Case, in Private Economic Benefits (in 2000 Dollars) to All Non-commercial Travelers in 2050, with Full Auto Ownership Costs Added In**

| | Scenario 1: Transit Improvement | Scenario 2: UGB | Scenario 3: Transit with UGB | Scenario 4: Transit with Pricing | Scenario 5: Transit with UGB and Pricing |
|---|---|---|---|---|---|
| All non-commercial trips | -$48,461 | $1,080,282 | $1,177,718 | $311,189 | $1,282,412 |
| Per trip | -0.02 | 0.58 | 0.63 | 0.16 | 0.69 |