MTI Report 04-02

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

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MODELING LONG-RANGE TRANSPORTATION AND LAND USE SCENARIOS FOR THE SACRAMENTO REGION, USING CITIZEN-GENERATED POLICIES

May 2005

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16. Abstract

The Sacramento, California region engaged in an innovative long-range visioning process during 2004 and 2005 in which the regional transportation planning agency defined and modeled several 50-year growth scenarios. The authors of this report worked with environmental and social equity community groups to define policies that would reduce emissions, serve lower-income travelers better, and preserve habitats and agricultural lands in the region. The community 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 with a land use policy for an urban growth boundary and a pricing plan for higher fuel taxes and parking charges for work trips. Using a new version of the MEPLAN model to simulate these scenarios over 50 years, the authors describe their findings regarding total travel, mode shares, congestion, emissions, land use changes, and economic welfare of travelers.

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EXECUTIVE SUMMARY

Effective urban planning and infrastructure investment rely on the ability to assess future needs today. Models are instruments for obtaining projections of what future conditions will be.

The ability of sophisticated urban and regional models to analyze policy alternatives is growing. As these models have improved, their use has been expanded.[1] Presently, many large Metropolitan Planning Organizations (MPOs) and state departments of transportation are developing, for the first time, integrated land use and transportation models. Table 1 presents a list of recent integrated land use and transportation modeling activities specifically for market-based spatial competition models. These agencies are responding both to local needs, expressed by their constituent cities and counties, and to external legal requirements, such as the National Environmental Policy Act (NEPA) and the Clean Air Act air quality conformity modeling rule. Driving this movement is the desire to create the ability for metropolitan regions to test alternative policies (both land development policies and transportation policies) and make more informed decisions regarding future impacts of current policies.

Table 1 Recent implementation of market-based spatial competition models in the United States

Land use models by type	Area used
UrbanSim—a disaggregate land use model with explicit floorspace developer designed by Paul Waddell at the University of Washington	Eugene, Oregon; Honolulu, Hawaii; Salt Lake City, Utah; and currently being fitted to Seattle, Washington.
PECAS—a disaggregate land use model with explicit economic interchanges developed by Doug Hunt and John Abraham at the University of Calgary	State of Oregon; currently being developed for the State of Ohio, and Sacramento, California

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.[2] The Sacramento Model Test Bed study was a side-by-side comparison of the SACOG travel model, a land use model that was used in conjunction with the SACOG travel model, and two fully integrated land use and travel demand models of which MEPLAN was one. The purpose of the study was to test and compare each model's policy analysis ability.[3] Each model was given identical data from the Sacramento region for model calibration. A trend scenario was run, as well as three policy scenarios. While the test bed study did not explicitly recommend one model over another, the findings, together with the previous model demonstration studies, led to MEPLAN being adopted by SACOG for regional policy analysis. SACOG implemented and funded the third incarnation of the Sacramento MEPLAN model, the model used in this study.

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 obtained 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.

The remainder of this report will proceed as follows. The following section will briefly detail the current modeling exercise taking place in the Sacramento Region and its relevance to this study. Next, the improvements of the current Sacramento MEPLAN model over past versions of this model will be discussed. This is followed by an explanation of the MEPLAN model itself. The Analysis and Methods section details the citizen outreach associated with this report as well as a description of the policy scenarios that were modeled. Results are then presented and discussed. Finally, a Conclusions section summarizes the findings in this report and discusses the limitations of our findings.

THE SACRAMENTO BLUEPRINT PROJECT

In the Sacramento, California region, the Sacramento Area Council of Governments (SACOG) is undertaking one of the more innovative modeling campaigns in the country. Titled the "Sacramento Region Blueprint Project," it is the bringing together of a suite of planning models to enable citizens, cities and counties to better plan for future growth, land development, traffic and air quality conformity within the six county (El Dorado, Placer, Sacramento, Sutter, Yolo and Yuba) SACOG region. This process included numerous citizens meetings at the neighborhood, county and region-wide levels.

At these meetings, the citizens, planners and local elected officials were able to test different land development policies and receive real-time feedback on the implications of each policy using the Place^{3}s (**PLA**nning for **C**ommunity **E**nergy, **E**conomics, and **E**nvironmental **S**ustainability) planning tool. (Place^{3}s is a GIS-based tool that allows users to experiment with alternative land use patterns and returns selected indicators to evaluate each alternative.) Throughout the process, organizers sought for collaboration between the SACOG staff and the various local planning staffs and elected officials. Once the region-wide policy scenarios were selected, they were to be fed into a market-based spatial competition model to allow a more robust evaluation of each alternative. The research reported here is from a parallel modeling process undertaken by the Urban Modeling Lab at the University of California, Davis under funding from the Mineta Transportation Institute.

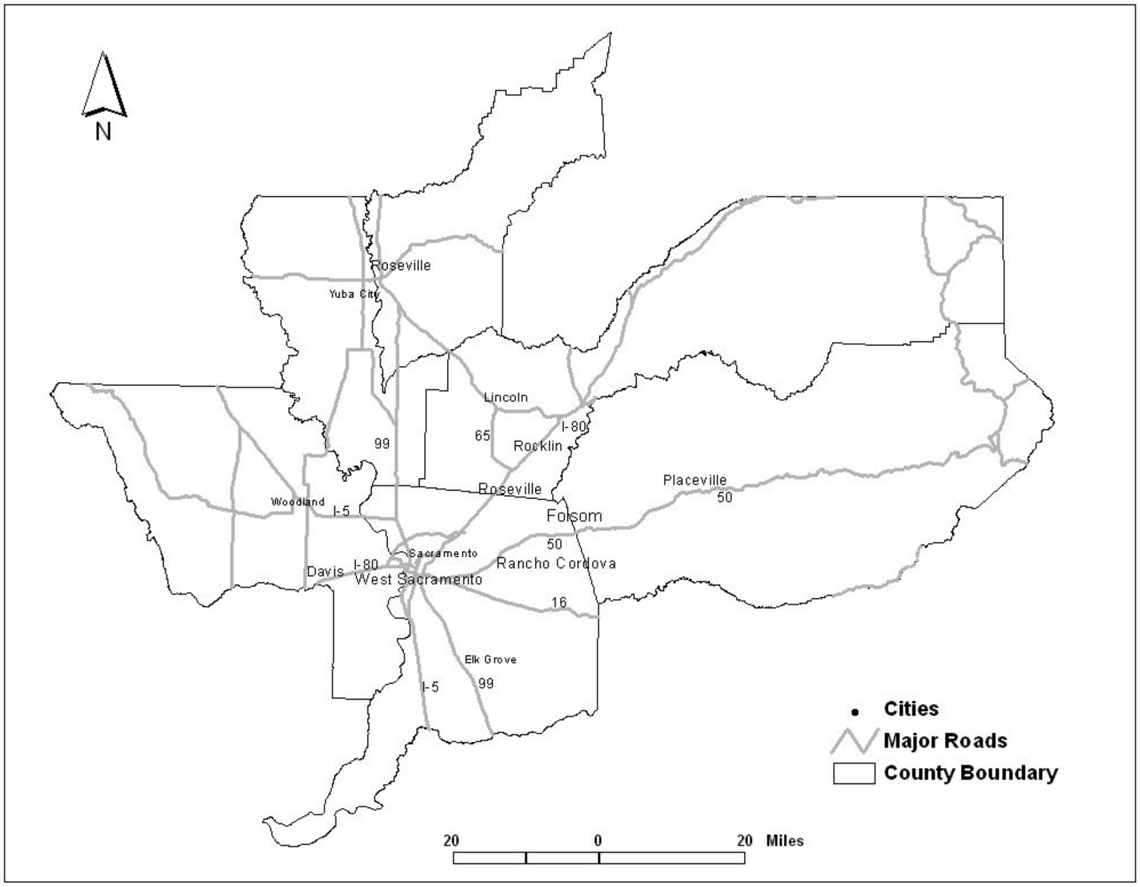

Figure 1 The Sacramento region

A PARALLEL PROCESS

In the Sacramento Region Blueprint Project, citizens are able to rearrange only two characteristics of the region, the density and the use of land. This was for a variety of reasons, not the least of which would be simplification of the process. Also, the SACOG staff has retained the elements of their current regional transportation plan, with some minor modifications.

The work reported here differs from the Blueprint Project in several ways. First, the outreach for this project is not as comprehensive. Specific community organizations were selected for this project rather than the public-at-large. Community organizations were selected in an effort to give voice to underrepresented groups. Second, the selected community organizations were given full access to the model (street networks, bus and light rail transit systems, land use, densities and growth boundaries). Third, rather than start at the neighborhood level and move successively up in scale, the citizen representatives were encouraged to think regionally in developing their policy scenarios. Finally, the results of this process were put directly into MEPLAN without Place^{3}s as an intermediate step.

The intermediate model (Place^{3}s) was not used for several reasons. First, it does not model the impacts of policy changes. It is a simple accounting tool that allows the users to make changes and then returns results. Second, no checks are made for feasibility. Unrealistic combinations of land uses can be input, whereas MEPLAN requires land uses to be socioeconomically related.

THE MEPLAN MODEL

The MEPLAN modeling framework is described in Hunt and Simmonds' 1993 article for *Environment and Planning*. The basis of the framework is the interaction between two parallel markets, a land market and a transportation market. This interaction is illustrated in Figure 2. Behavior in these two markets is a response to price and price-like signals that arise from market mechanisms. In the land markets, price and generalized cost (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.

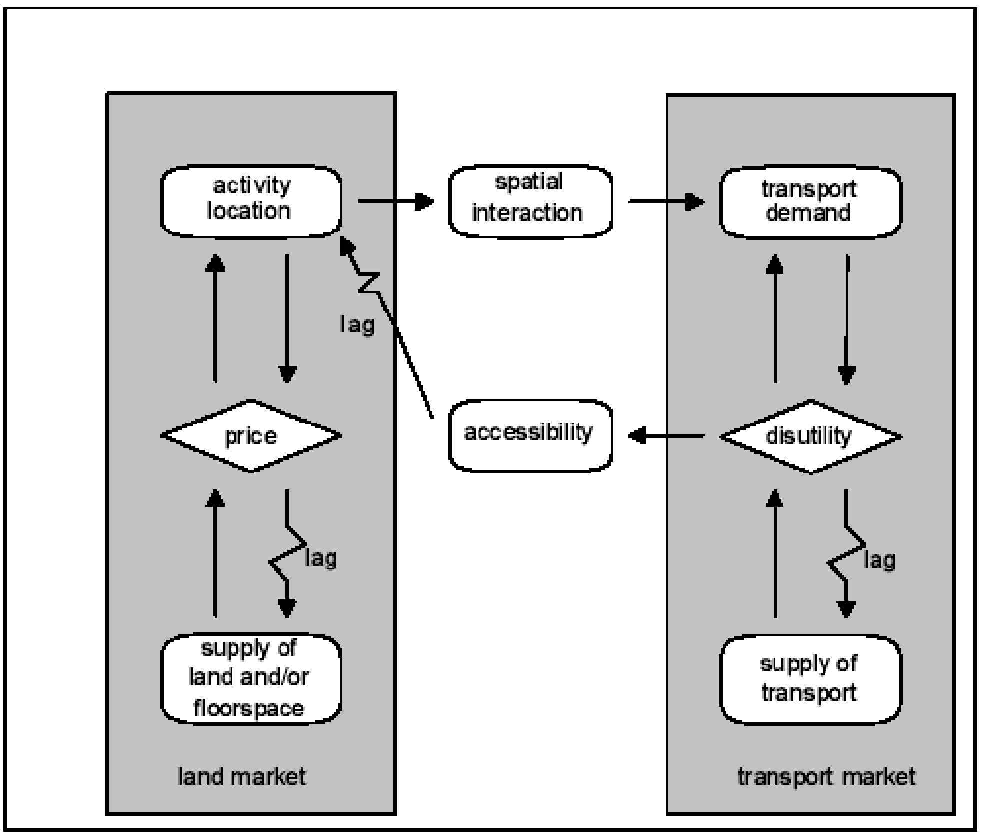

Figure 2 System of two types of markets: Markets in land and in transportation and the interactions between them form the basis of the MEPLAN framework. Reproduced with permission from Abraham, 2000.

THE SOCIAL ACCOUNTING MATRIX (SAM)

The cornerstone of the land market model is a spatially-disaggregated social accounting matrix (SAM)[4] or input-output table[5] that is expanded to include variable technical coefficients and uses different categories of space (e.g., different types of building and/or land). Discrete choice (logit) models of location choice are used to allocate volumes of activities to geographic zones in the different sectors of the SAM. The attractiveness or utility of zones is based on the cost of inputs (which include transportation costs) to the producing activity, location-specific disutilities, and the costs of transporting the resulting production to consumption activities. The resulting patterns of economic interactions among activities in different zones are used to generate origin-destination matrices of different types of trips. These matrices are loaded to a multi-modal network representation that includes nested logit forms for the mode choice models and stochastic user equilibrium for the traffic assignment model (with capacity constraints). The resulting network times and costs affect transportation costs, which then affect the attractiveness of zones and the location of activities, and thus the feedback from transportation to land use is accomplished.

The framework is moved through time in steps from one time period to the next, making it "quasi-dynamic." 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 (see Figure 3). 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 and Simmonds for descriptions of the mathematical forms used in MEPLAN, and Johnston et al.'s 2001 publication for a more complete explanation of the model structure.

The specific structure of the Sacramento MEPLAN model is shown in the diagram in Figure 4, and Table 2 defines the categories in the diagram. The large matrix in the middle of the diagram lists the factors in the land use submodel and describes the nature of the interaction between factors. A given row in this matrix describes the consumption needed to produce one unit of the factor, indicating which factors are consumed and whether the rate of consumption is fixed (*f*) or price elastic (*e*).

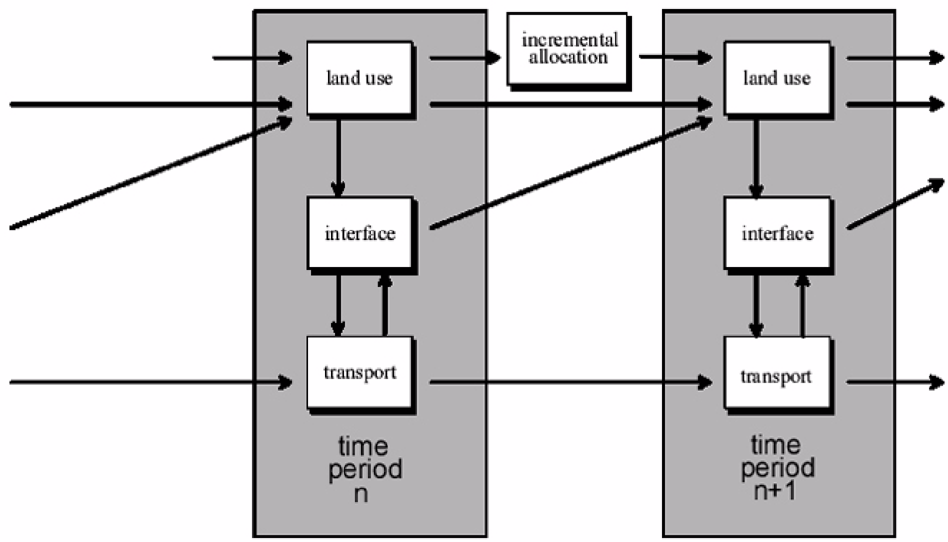

Figure 3 MEPLAN submodels and their interactions: Temporal dynamics are simulated by ordering the sequence of interactions among the program modules at adjacent points in time. Reproduced with permission from Abraham, 2000.

Table 2 Description of categories in Figure 4

Type of category	Category name	Category description
Industry and service	AGMIN	Agriculture and mining
	MANUF	Manufacturing
	OFSRV-RES	Services and office employment consumed by households
	OFSRV-IND	Services and office employment consumed by other industry
	RETAIL	Retail
	HEALTH	Health
	EDUCATION	Primary and secondary education
	GOVT	Government
	PRIV EDU	Private education
	TRANSPORT	Commercial transportation
	WHOLESALE	Wholesale
Households	HH LOW	Households with annual income less than $20,000
	HH MID	Households with annual income between $20,000 and $50,000
	HH HIGH	Households with annual income greater than $50,000
Land use	AGMIN LU	Land used for agriculture
	MANUF LU	Land used for manufacturing
	OFSRV LU	Land used for services and office employment
	RETAIL LU	Land used for retail
	HEALTH LU	Land used for health
	EDUCATION LU	Land used for education
	GOVT LU	Land used for government
	RES LU	Land used by residences

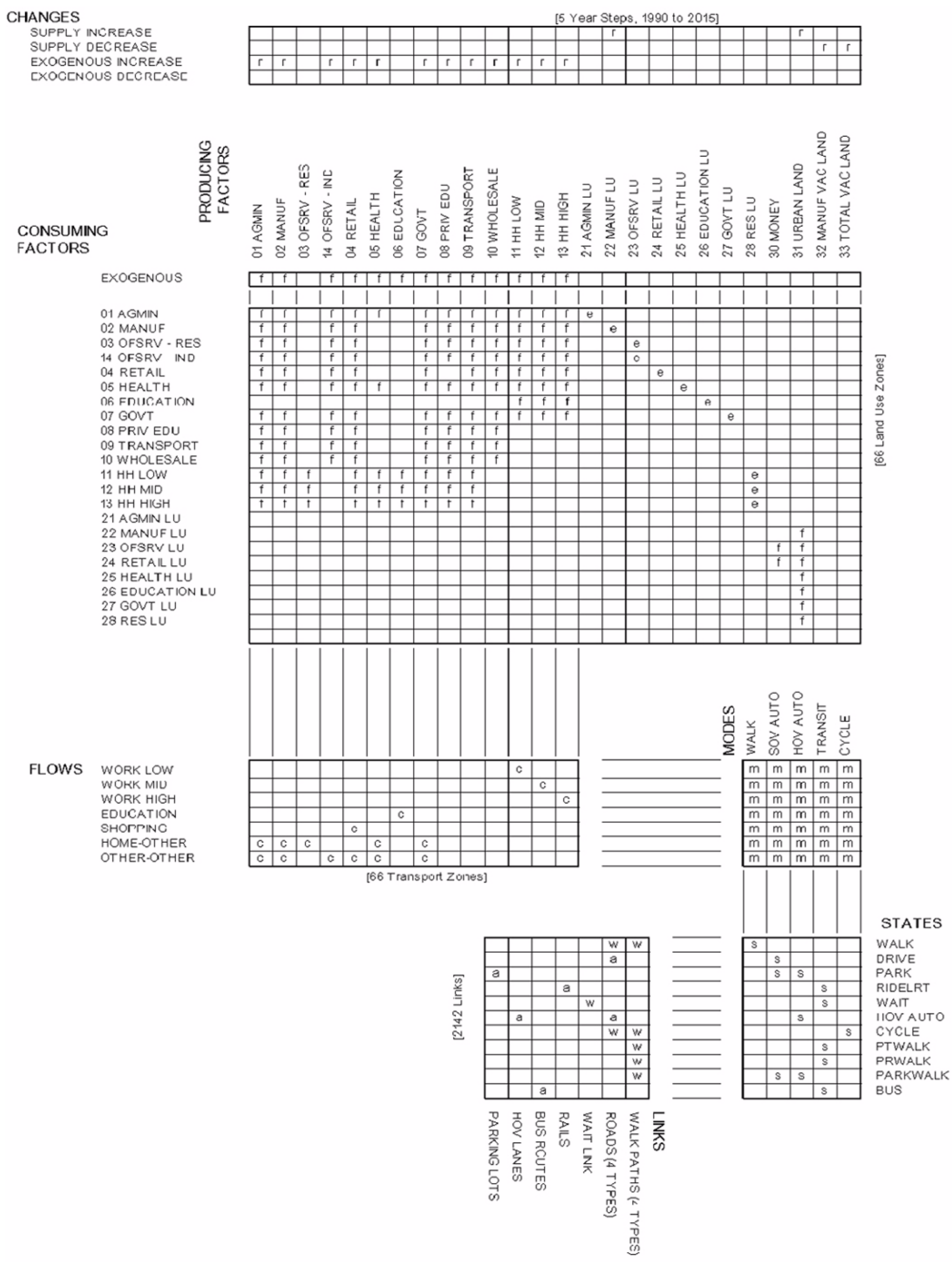

Figure 4 The MEPLAN matrices

The Sacramento MEPLAN model uses eleven industry and service factors that are based on the SAM and aggregated to match employment and location data. Households are divided into three income categories (high, medium, and low) based on the SAM and residential location data.

The consumption of households by businesses represents the purchase and supply of labor. This MEPLAN model does not have the number of workers by education level in the households, which would result in a more accurate matching of workers with jobs. This disaggregation can be done, but it was not part of our study proposal. The consumption of business activities by households represents the purchase of goods and services by consumers.

Industry and households consume space at different rates and have different price elasticities, and thus there are seven land use factors in the model. Constraints are placed on the amount of manufacturing land use to represent zoning regulations that restrict the location of heavy industry. Each of these land uses (except agricultural land use) locates on developed land represented by the factor URBAN LAND. Two factors are used to keep track of the amount of vacant land available for different purposes in future time periods (MANUF VAC LAND and TOTAL VAC LAND), and the development process converts these two factors to URBAN LAND. The MONEY factor is a calibration parameter that allows differential rents to be paid by different users of the same category of land, meaning that a firm would pay a higher rent for the same category of land in the downtown zone than it would in a more rural zone.

MAPPING THE MATRICES

The single-row matrix, just above the large matrix in Figure 4, shows activity that is demanded exogenously, which includes exporting industry, retired households, and unemployed households. This corresponds to the "basic" economy in a Lowry model.[6]

The matrix directly above, at the top of the diagram, shows the structure of the incremental model that operates between time periods. The *r*'s for the industry and household factors indicate the economic growth in the region, and the *r*'s for the land use factors show how vacant land is converted to urban land.

The matrix on the left, below the large matrix, indicates the structure of the interface between the land use and transportation submodels. Each row represents one of the matrices of transportation demand and indicates the producing factors (in the corresponding columns in the matrix above) whose matrices of trades are related to that flow.

The remaining three matrices, at the bottom, show the structure of the transportation model. Five modes are available, and each mode can consist of several different types of activity on different types of links. The matrix directly to the right shows that all modes are available to all flows (*m*). The matrix below this, on the right, indicates the travel states (*s*) that make up each mode. The matrix on the left shows which travel states are allowed on each transportation network link and whether capacity restraint is in effect (*a*) or not (*w*). The design of the mode choice and assignment models is based on the Sacramento Regional Travel Demand model. A more detailed description of the Sacramento MEPLAN model design can be found in Abraham's 2000 dissertation.

IMPROVEMENTS FROM SAC-MEPLAN2 TO SAC-MEPLAN3

In past research, a four-county (El Dorado, Placer, Sacramento, and Yolo counties) version of MEPLAN was used, with a 1990 base year. Some of the needed input data was not available when this model was calibrated, which led to a less than ideal model calibration. Many inputs, for example, represented expert "best guesses." In addition, the travel networks also suffered as a result of inadequate budget. The past version of the Sacramento MEPLAN model (SacMEPLAN2) ran on a "sketch" travel network that omitted most collector streets. By limiting the road network, it is conceivable that the travel outputs would be too sensitive to road improvements.

The current model being used for this report, SacMEPLAN3, is not an academic/research model but was funded by SACOG. This incarnation of the model enjoyed a more complete calibration and longer evaluation period. This model contains all six counties (adding Yuba and Sutter counties) in the SACOG region. It represents the full travel network and has better input data. The calibration of this model was closely scrutinized by SACOG staff and the authors of this report. The combination of better inputs, better model calibration, better travel network representation, and a more distant horizon year make this newer installment of the model more relevant to policy analysis. Table 3 summarizes several of the improvements from SacMEPLAN2 to SacMEPLAN3.

Table 3 Comparison between SacMEPLAN2 and SacMEPLAN3

	SacMEPLAN2	SacMEPLAN3
Number of counties	4	6
Number of internal zones	58	71
Size of travel network	2,124 links	14,558 links
Base year	1990	2000
Horizon year	2020	2050
Time step	5 year	2.5 year

This version was also calibrated on more accurate floor space rent data than were the earlier two versions. Lead researcher Robert 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. Average monthly per-square-foot rental rates by zone for industrial, office, retail, multifamily and single-family floor space types were projected in sequence onto a screen, and the real estate professionals were asked if the mean seemed correct and if the research had missed zones with high rents as well as low rents. The model requires a range of rents to see where demand is high or low. The researchers did the residential land uses separately for the three household income classes, and also asked for the number of acres available for redevelopment in each zone and which zones were “hot” for future development of each type. This process resulted in a greater range of rent values for each activity type and a better grasp of the level of demand for each zone.

ANALYSIS METHODS

COMMUNITY OUTREACH

There are numerous community organizations in the Sacramento area that are concerned with a variety of issues. For this study, researchers wished to work with groups that were concerned with issues related to land use/development and transportation. To optimize time and the impact of this project, umbrella groups (large organizations that are made up of several member groups, each having their own citizen/concern base) were considered. The Environmental Council of Sacramento (ECOS), a regional umbrella group that represents environmental and social equity organizations, was ultimately chosen. This research group has worked less formally with ECOS in the past.

Frequent meetings were held during the fall of 2003 and winter of 2004 (roughly two a month) with ECOS, and Sacramentans for Transportation Equity (SAC-TE), a transportation equity group. Researchers from the Urban Modeling Lab attended roughly half of these meetings. The meetings had varying purposes and attendance, ranging from one-on-one meetings with selected individuals to larger presentations and discussions. Attendance at these meetings ranged roughly from 15 to 35 participants.

In the initial meetings, a cursory overview of the MEPLAN model was provided to the groups as well as an outline for this project. Their challenge was to create a comprehensive and cohesive vision for the Sacramento region that we would then convert into an operational scenario to input into the model. The groups divided the tasks into a land use vision and a transportation vision. These task groups met independently and presented their ideas at the collective meetings. These citizens groups generated the policy scenarios modeled and reported here.

IMPORTANT OUTCOMES

These meetings produced several important outcomes. First, a set of maps was produced with new transit lines (region-wide bus rapid transit, for example). Second, an urban growth boundary and zoning changes (to allow higher-density infill) were decided upon. Third, the process facilitated both groups in developing region-wide vision statements for land use and transportation. Prior to this exercise, ECOS was primarily concerned with Sacramento County, as opposed to the entire six-county metropolitan area.

There was an early struggle among the participants over how this process would take place. Some of the participants wanted to know all model inputs and exactly how the model worked in an effort to achieve the best or most desired outputs. While these community organizations were given access to the model inputs and outputs, we discouraged this approach of simply "gaming the model" in favor of a visioning process in which the participants came up with a set of ideals or goals and then worked on operationalizing them into useable scenarios.

Another challenge faced by the participants was the sequencing of road projects, transit improvements, land policies, and transportation policies. The SACOG six-county MEPLAN model has a 2050 horizon year. With 50 years of sequencing to work with, numerous possibilities were presented by the citizens and discussed in these meetings. The outcomes of these meetings are represented in the five scenarios that were modeled and are explained below.

THE BASE CASE SCENARIO

The Base Case scenario was similar to the SACOG trend scenario used in the Blueprint process, and 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 market demand influence them, in other words, few regulatory land use controls are in place in the Base Case scenario. This is not unlike the actual condition in the six-county region. This land use scenario was derived from the local general plans of the cities and counties in this region and efforts were made to represent their land use strategies.

All scenarios used virtually the same internal populations in the various model years: 1.9 million in 2000, 2.7 million in 2025, and 3.6 million in 2050. 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 agricultural 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. Like most rapidly growing regions, this one will have difficulty showing air quality attainment in the future.

Citizens groups are questioning low density, single-use developments on previously undeveloped land for increasing travel and emissions. El Dorado County has historically allowed this type of development, while Placer County has kept growth confined mostly to the I-80 corridor in the past, but recently has begun to grow in outlying areas. Sutter and Yuba counties protected agricultural lands in the past but seem to be rezoning large areas for development now. Sacramento County has seen its urban growth boundary come under fire more often in recent years, but so far has withstood these pressures. However, new cities have incorporated recently, and they are annexing lands for growth. Yolo County has historically been the most resistant to these pressures 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. Appendix A contains an abbreviated description of the major network improvements by model year.

Our outreach and modeling work was being conducted in 2004. Projects scheduled in the model for a 2005 completion date were considered too far along to be impacted by this work; therefore, they were not on the table for the citizens groups to manipulate and are not detailed here since many of them are already on the ground.

POLICY SCENARIO

The overarching idea behind the scenarios generated by these citizens groups was to improve the quality of life in the region for both the current 1.9 million residents and the estimated 1.7 million additional residents expected by 2050. They felt strongly that travel 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 limiting HOV lane additions; 2) dramatically improve transit service; 3) use a strict urban growth boundary, and promote infill development; and 4) introduce parking charges and higher fuel taxes.

Scenario 1: Transit Improvements

Scenario 1 consists of massive improvements to the transit service and facilities in the region. All road projects beyond 2005, including HOV lanes, were canceled (removed from the model). Numerous new bus rapid transit (BRT) lines were added and most of the BRT lines from the Base Case were carried over as well. For our purposes, BRT refers to high-speed bus lines with signal preemption that make a limited number of stops and at times have dedicated lanes. 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. All BRT lines were given an initial headway of 20 minutes, with the exception of 50BR1/50BR2, which maintained its 10-minute peak hour headway from the Base Case. Appendix B contains a summary of these transit improvements.

The citizens attempted to create a transit-only scenario with roughly the same capital costs as the Base Case, to make the comparison easier and fair.

Figure 5 shows the LRT extensions and new BRT lines in this scenario. BRT runs to major outlying cities (Davis, Marysville/Yuba City, Auburn, and Placerville), as well as throughout the urbanized central area of Sacramento County.

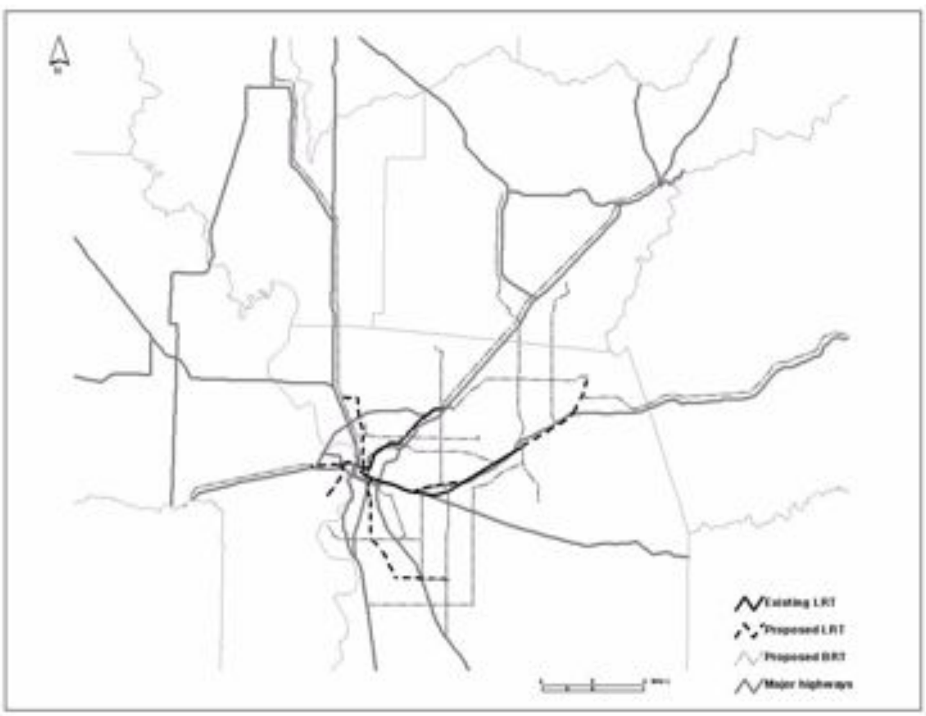

Figure 5 Scenario 1: Light rail extensions and new bus rapid transit lines

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 central business district (CBD) without incurring increased travel costs. In other words, the roadway and transit improvements may facilitate sprawl-type growth in the outer zones by reducing travel times from the outer zones to all other zones and especially to the CBD.

In order to prevent this, an urban growth boundary (UGB) was implemented by restricting the amount of land available for development in the outer zones. Figure 6 presents the growth boundary. The shaded zones represent zones in which development was allowed to occur. The non-shaded zones had all developable land converted into a protected classification that did not allow development of any kind. 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 urban growth boundary.

It should be noted that the shaded area can be misleading. The shaded area represents zones where growth was allowed to occur. Within each zone the actual amount of land available varies. For example, the two westernmost zones are located in Yolo County, which already had strict growth controls, so while growth is allowed to go into these zones, the amount of land available within these zones for development is quite modest. This is in contrast to the easternmost zones in the region, which have no growth controls, and large amounts of these zones are actually zoned for development.

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

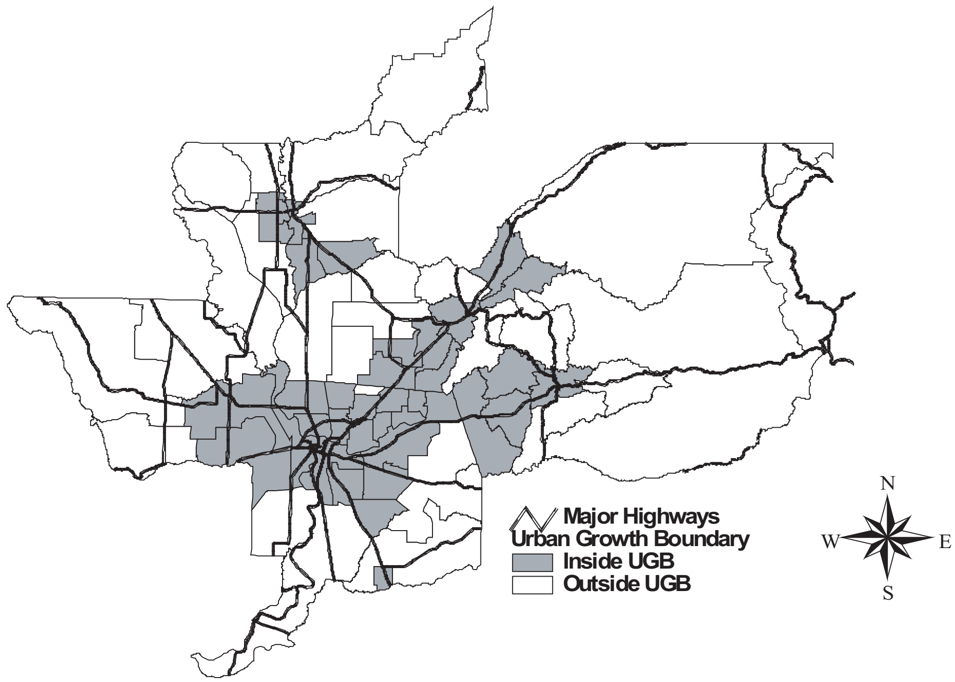

Figure 6 Urban growth boundary shown in the shaded zones

Scenario 3: Transit Improvements with Urban Growth Boundary

Scenario 3 utilizes the networks created for Scenario 1 (transit improvement scenario), adding the tight urban growth boundary created for Scenario 2. The massive capital improvements of Scenario 1 (transit improvements, as opposed to the roadway improvements of the Base Case) improve travel accessibility within the zones affected by the creation of these new, high-capacity, high-speed transit modes. This increased accessibility means that people and jobs can move farther from the CBD without incurring increased travel costs. In other words, the transit improvements may facilitate some sprawl growth in the outer zones, although in different patterns from the Base Case, by reducing travel times from the outer zones to other zones and especially to the CBD. 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

One of the reasons vehicle miles traveled (VMT) continues to rise is due to the relatively low cost of driving per mile.[7] Once the car has been purchased, it becomes a sunk cost and therefore isn't typically considered when deciding which mode to take (e.g. SOV, HOV, transit, walk, or bike), which destination to select (how far to drive), or whether or not the purpose of the trip is worth the cost. Because of this, the community organizations decided that a pricing scenario was needed to see if policies such as mandatory parking charges or higher gasoline taxes could be effective tools to limit the amount of driving and, therefore, the amount of air pollution generated by automobiles.

In this scenario, the networks that were created for Scenario 1 were used in combination with a gas tax and a parking charge. The parking charge was applied at the destination of work trips in the amounts of $6.00 per trip in the central business district and $2.00 per trip everywhere else. This parking charge was only applied to work trips. Charging for work-trip parking is likely to occur in the next decade or two for a variety of reasons, especially in regions with adequate transit service. The gas tax was the equivalent of $1.00 per gallon and was applied globally to all automobile trips. In reality this wouldn't have to be a gas tax per se. If the actual price of gasoline rose by one dollar a gallon, it would have the same effect (or any combination of rising fuel prices and taxes). This is a modest price increase over 50 years, given that most experts predict a real price increase by 2020. If the economies of China and India continue to grow rapidly, and if Russia's economy recovers, demand will push up prices sooner.

Scenario 5: Transit Improvements with Pricing and Urban Growth Boundary

In Scenario 5 the previous two scenarios were combined to create a scenario with improved transit service, parking prices and an increased gasoline tax, and the urban growth boundary.

MEPLAN is a quasi-dynamic model in which the interplay between the various policies can only be understood with the model explicitly accounting for the effects of them collectively. For this reason, the fifth scenario was run.

The methods used to calculate the various results are described within the discussion of the results, so the methods will be clearly related to the obtained results.

RESULTS

It should be noted that for the base case and all scenario runs reported here the population and employment totals (year-by-year) remained relatively constant from one scenario to the next. (MEPLAN allows additional people to enter or leave the region if conditions warrant it, typically in relatively small amounts.) All changes reported here are a result of behavioral changes of the households and employers being modeled. MEPLAN allows households and employers to change both location and travel choices in response to changes in the land market and travel conditions. Efforts were made to maintain the base case assumptions in each scenario except for the policy changes noted previously in the description of each scenario. The MEPLAN travel model only includes travel for the three-hour a.m. peak period (hours between 7 and 10), and so we are not accounting for all daily trips. In addition, work trips are a high proportion of modeled trips.

TRAVEL CHANGES

Base Case vs. Scenario 1: Transit Improvements

First, note that overall transit share falls in 2050, compared to 2025, in the Base Case. This is due to the availability of cheap land beyond the reach of transit coverage. As more and more households move to this land, transit becomes less available.

This (Scenario 1 versus the Base Case) is really a comparison of a large number of road improvements versus a large amount of transit improvements. As can be seen in Tables 4 and 5, halting road expansions while dramatically improving transit service lowers vehicle miles traveled (VMT) in 2025 and 2050. Mode shares also change as more households choose to take transit and fewer are driving.

These results demonstrate that, given the choice, many households that now choose to drive may actually be amenable to transit. In this region, as in many others, the inability of transit to connect many trip origins and destinations in one transfer or less makes it a poor substitute for the automobile. By improving the level of service and availability of transit, this scenario demonstrates the ability of transit improvements to draw drivers out of their vehicles and onto mass transit, particularly high-speed transit modes such as bus rapid transit and light rail transit.

Table 4 Model outputs for the year 2025 by scenario

	Base Case	Scenario 1: Transit Improvement	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 average travel speed from base						
All trips						
SOV	16.5 mph	-3.98%	1.95%	0.29%	6.59%	11.0%
HOV	19.6 mph	-2.83%	3.50%	0.78%	4.55%	8.14%
Work trips						
SOV	15.7 mph	-6.71%	3.35%	-0.33%	5.36%	16.55%
HOV	18.1	-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
SOV	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
HOV	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
SOV	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

	Base Case	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
HOV	9.67	8.98	9.01	8.17	6.38	5.55
Bike	4.90	5.97	6.38	6.57	19.60	19.70

(SOV=Single-occupant vehicles; HOV=High-occupant vehicles)

Base Case vs. Scenario 2: Urban Growth Boundary (UGB)

The UGB scenario is different from the others considered here. While transit improvements and pricing strategies entice people to move closer 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 6 and 7). It also draws travelers to transit, although not quite as strongly as the transit scenario (Tables 4 and 5). 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 Scenarios C and D from their Regional Blueprint visioning process, and so one can conclude that Scenario 1 reduces VMT more, especially in 2050. It can also be observed that in Scenario 3, where the model improves only transit and keeps the UGB policy, VMT are reduced by twice as much as Scenario 2.

Table 5 Model outputs for 2050 by scenario

	Base Case	Scenario 1: Transit Improvement	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 average travel speed from base						
All trips						
SOV	13.5 mph	-2.07%	2.43%	1.95%	10.29%	13.56%
HOV	16.4 mph	-3.04%	2.44%	1.49%	3.64%	7.73%
Work trips						
SOV	12.5 mph	-4.29%	3.80%	1.69%	12.49%	21.87%
HOV	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
SOV	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
HOV	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
SOV	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
HOV	8.74	7.70	7.88	7.07	5.00	4.17

	Base Case	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
Bike	8.91	11.72	11.39	12.13	25.98	24.19

Base Case vs. Scenario 3: Transit and Urban Growth Boundary

The combination of transit improvements and a UGB reduce VMT by roughly 15 percent by 2025 and roughly 20 percent by 2050 (see Tables 4 and 5). Not surprisingly, this combination also produces strong downward shifts in the mode share of single- and high-occupant vehicles while improving the mode share of transit, walk, and bike. This scenario is clearly better than Scenario 2, which is very close to the scenario adopted by SACOG in its charrette process in 2004, at lowering VMT and the auto shares.

It is interesting to note that the impacts of this scenario are nearly the sum of the impacts of its components. This suggests either one of two behaviors. First, the two strategies might be affecting different groups. For example, the transit improvement scenario wouldn't have much impact on households locating in the outer zones (people to whom the availability of transit is limited, even in this scenario). Conversely, the UGB scenario may bring people into zones where they can choose transit, but, because it doesn't improve transit, those who might be affected by the transit scenario are unaffected. Notice that the UGB scenario lowers VMT, which lowers congestion on the travel network, which would have an opposite impact on people already living within the urban core and using cars, but who are teetering on the transit/auto choice.

The other plausible explanation for the cumulative relationship of these policy scenarios is that it is simply chance, meaning that the combined effects raise the utility of taking transit, which raises its mode share and lowers VMT. The fact that they are nearly double is merely an artifact of the model structure. One might expect a dampening effect, as additional policies are modeled together. At least in this case, the dampening effect does not appear. Also, there may be a synergism where there is some substitution but also may be complementary over time.

Base Case vs. Scenario 4: Transit and Pricing

Due to the market-based nature of MEPLAN, researchers supposed that the pricing policies modeled in Scenario 4 would have large impacts on the model outputs. As can be seen in Tables 4 and 5, 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 significantly raises the costs of driving. Table 6 shows that location changes are not as high as those caused by the UGB scenario. This suggests that a market-based solution, such as parking charges and gasoline taxes, may have similar VMT and even better mode share impacts than a regulatory policy like a UGB. Readers should note, however, that the UGB appears to reduce growth in the outer zones more than the pricing scenario. Thus, it may be more appealing in terms of impacts on habitats and agricultural lands. Researchers note that this peak-period travel model in MEPLAN has a high proportion of work trips, which are affected by the parking charges. Daily mode shares and VMT would not be affected as much.

Base Case vs. Scenario 5: Transit, UGB and Pricing

By far the largest reduction in VMT and the greatest shifts away from automobile modes occur when all three policies are modeled together. Tables 4, 5, 6, and 7 demonstrate fairly radical 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 other travel modes, including transit, walking, and bicycling in greater numbers. Researchers expect synergism among these policies, as transit has high service levels and so can handle the travelers priced out of cars. Again, the pricing will have strong effects because of the peak period.

Looking at all scenarios, travel changes were larger in 2050 than in 2025, as some transit improvements occur in 2035 and there is more time for transit and the other policies to affect land development and locators. Also, 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 seemed 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. Floor space rents were also reasonable, as well as travel times.

CONGESTION

The researchers defined congestion as those links with a volume/capacity ratio of 1.00 or greater. Due to the complexity of the network and the software, we calculated congestion only on freeway and expressway links. It was assumed 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. 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, it is expected that pricing scenarios will 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 in 2025, except Scenario 1. The poorer performance of Scenario 1 is probably due to the reduced freeway lane-miles and transit not yet having short enough headways in 2025.

Things are more complex in 2050. All scenarios have higher congestion levels than in 2025 and all have roughly the same congestion levels. This is due to all the freeways leading into the CBD being saturated and traffic being shunted to surface streets, which we are not measuring. The slightly higher congestion in Scenario 1 is probably due to the increase in CBD employment in this scenario. Scenarios 3 and 5 also have congestion levels about the same as the base case, also probably due to increases in CBD employment. All scenarios increase average auto speeds, compared to the base, except Scenario 1, as occurred in 2025. This indicates that building even a very strong transit system will not work well with a sprawl land use plan for the region. These are small changes and it is believed that the strong benefits for the low-income travelers and the large reductions in VMT and emissions make this scenario beneficial overall. Scenarios 4 and 5 have the highest average speed for autos.

EMISSION CHANGES

As part of the research for this publication, the California emissions model was not run. Past studies have revealed 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.[8] So, the emissions reductions will be very similar to the VMT reductions. Daily emissions rankings would 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 a new state emissions inventory with more sport utility vehicles (SUVs) and light duty trucks in the region's current and future vehicle fleets, and also due to increases in most types of emissions per mile for the higher vehicle speed classes. There is considerable interest among citizens and elected officials in this region in reducing VMT and emissions.

A COMMENT ON SACOG'S BLUEPRINT SCENARIO D

In the recent Regional Blueprint process, SACOG did a series of neighborhood design charrettes throughout the region and then did countywide charrettes. Finally, they did a regional meeting with over 1,000 attendees. At this meeting, the audience chose two scenarios with UGBs, but with the adopted regional transportation plan networks (which are our Base Case networks). So, researchers performed Scenario 2 with a UGB and the Base Case policy of new freeways and freeway widenings with moderate transit improvements, to represent the SACOG Scenario D. Scenario 3 represents the ECOS environmental group's transit-only transportation networks, along with the same UGB. It is noted that Scenario 3 reduces VMT and emissions in both years about twice as much as does Scenario 2. Scenario 3 is slightly more congested and has slightly lower average auto speeds than does Scenario 2, but these costs may be acceptable if the region needs to reduce emissions substantially. If the outer counties do not cooperate and adopt UGBs, then Scenario 4 (transit with pricing) could become necessary.

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

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 network (e.g., road improvements and changes in the coverage and level of service of mass transit). Given that this is a 50-year modeling exercise, location shifts are an important factor in forecasting how the Sacramento region will grow and change in response to the policies being modeled. In past work, this research has shown that an urban model more strongly differentiates among scenarios than does a travel model, due to synergistic land use effects.[9] The scenarios run in this study produced fairly substantial shifts in the location of households and employment. From a travel perspective, the closer activities are to each other, the less travel demand is placed on the travel network. From a conservation perspective, the closer activities are together, the less land is needed, thus preserving habitats and agricultural lands.

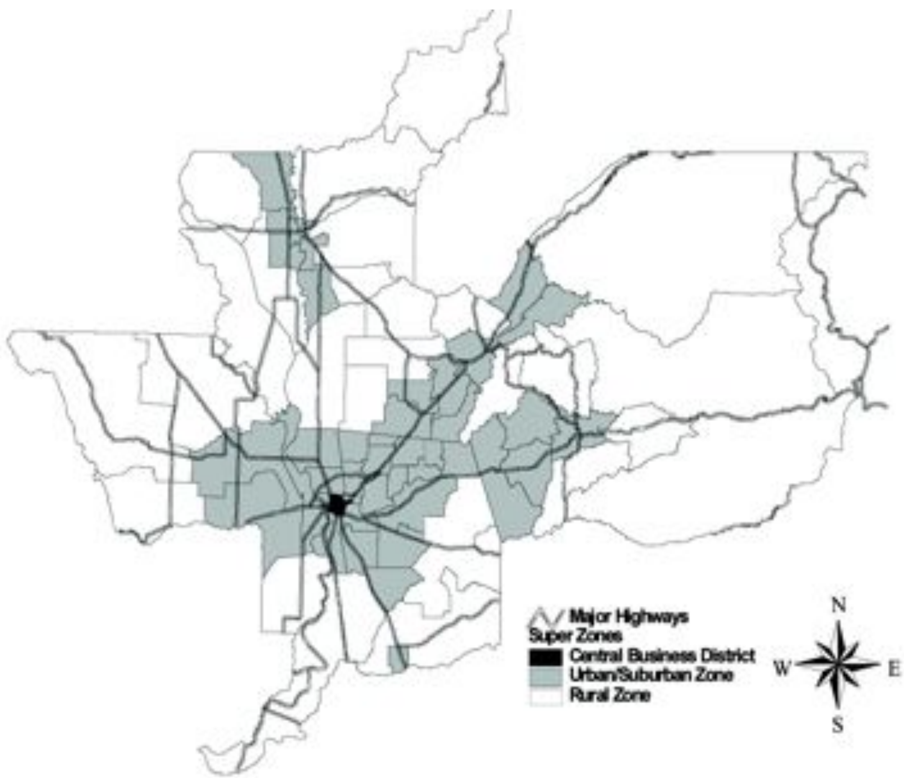

Figure 7 Super zones created for location shift analysis

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 (Figure 6). The zone comprising the central business district (CBD) of Sacramento was left alone due to its unique density, land use pattern, 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 zone (urban/ suburban zone). Readers should note that these two groups are also the zones that are included within the UGB created for Scenarios 2, 3, and 5. The final zone is the rural zone, comprising the zones with limited, scattered rural development. These zones were excluded from the UGB because of the desire to maintain open space and preserve agricultural lands. The shifts of total employment and population by these superzones (not just new growth) are shown in Tables 6 and 7.

Table 6 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	0.121%	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%

Notice that the UGB accounts for the largest location changes. The mode shifts from driving to transit, discussed in Tables 5 and 6, are facilitated by location shifts. Employment and households shifting from the rural zone to the urban/suburban and CBD zones 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. Also, the transit system is complete but does not yet have short headways, so access to the CBD is worse than in the base case. In Scenario 4, the CBD loses employment in 2025 because of the higher parking charge in this zone ($6 vs. $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 percent, and the transit plus pricing scenario (4) reduces them one to four percent 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. The UGB scenarios, of course, cause large reductions in the outer ring in both years.

The detailed data for changes in total households and employment by zone are given in Appendices C and D, to give the reader an idea of this critical model output at this level.

Table 7 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%

ECONOMIC BENEFITS FOR TRAVELERS

The researchers calculated changes in traveler economic welfare, using the compensating variation (CV) measure. See Rodier and Johnston's 1998 publication for a description of this method, as applied with 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) between zone "i"and all zones "j." The CV is really a weighted disutility that allows the analyst to see the total amount of effort, in time and money, being expended for travel purposes.

This calculation was made for each scenario and compared with the base case (Policy Scenario minus Base Case). A lower CV in total or by flow type indicates that people are spending less time and money on travel and therefore are receiving economic benefits. Small and Rosen (1981) show that the disutility log sums from a mode split model can be used to obtain economic welfare measures for travelers. 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.

The model gives separate benefits for three traveler income classes for the worktrip. This allows the understanding of vertical equity (equity by income classes) for our scenarios. The benefits for the non-work trips probably have the same signs as the benefits for the work trips, so it is believed that this measure can be used as a surrogate for overall traveler equity for the a.m. peak period.

For all other trip purposes, it is possible to get the measure only for all travelers together, so the total benefit for all trips is provided. This measure is then the indicator for aggregate economic welfare in the scenario.

All economic measures are the difference of the policy scenario minus the base case, or the region-wide net benefits of the policy scenario, expressed as a three hour a.m. peak-period value (for an average weekday), including about 1.9 million trips. From past experience, it is believed that the daily welfare measures would rank the same, but would be three-to-four times as great for aggregate welfare. Per trip welfare would be somewhat smaller, due to lower congestion and time costs, in non-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 it is not used. 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. 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 the moral position is taken that a UGB is desired regardless of effects on locator surplus, then those losses are not considered. One could espouse this view if habitat protection were critical in the region.

In the obverse, there may be situations where travelers experience a loss of welfare but a gain in locator welfare, but the latter is not calculated in this research. 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 having higher travel costs, and so experience negative traveler welfare compared to the other scenarios. Again, the number of such households is relatively small, about 20 percent of the region's households.

This research also notes that 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 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. The welfare of the middle- and high-income travelers would also improve, perhaps making their welfare become neutral in Scenario 4, which would make overall welfare become roughly neutral also.

The parking charges for work trips 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, it is expected the labor market will compensate workers with equivalent higher wages. If one 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, research has 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.[10]

Another issue is whether capital and operation costs for each scenario were deducted in the analysis. The calculation can be done without this by indicating the calculations are simply a private, or users', welfare analysis. It can also be said that researchers are comparing scenarios with similar costs, and so they don't affect the analysis 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 and operation costs are spread over many years. Johnston and Rodier's 1998 and 1999 publications revealed that in situations evaluating various transit, UGB, and pricing scenarios, it was found that these project costs were small and did not affect the welfare results significantly.

Having stated all of the reservations above, this research group still wishes to emphasize that this welfare measure is a more comprehensive measure of congestion than is the road congestion measure above, or the average auto speed measure. They both omit the 20-30 percent 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.

Table 8 gives the aggregate welfare changes, and it is apparent 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 three-to-four times as great, which is quite significant. One may think of these benefits as increases in the disposable income of the households. One expects that most of these savings would be spent in the regional economy. As mentioned above, if the fuel taxes and parking charges were refunded, Scenarios 1 and 4 would likely be positive overall or neutral. All scenarios are positive for the low-income households 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 8 Total changes, from the Base Case, in economic benefits (in 2000 dollars) to commuters by income class and to all non-commercial travelers in 2050 (for the a.m. peak period)

	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	$67,240	$68,597	$16,722	$36,898
Medium income commuters	-$57,270	$154,090	$124,474	-$128,641	$69,617
High income commuters	-$20,453	$92,170	$60,147	-$159,262	-$49,140
All non-commerical trips	-$455,377	$811,270	$489,274	-$305,614	$429,009

Table 9 offers 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. So, overall, the economic benefits to the region of a UGB policy are very large and a strong transit policy greatly benefits the low-income travelers. Also, it is noted 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, who believe that the Sacramento region needs better transit, infill with UGBs, and pricing of auto travel.

Table 9 Per trip changes, from the Base Case, in economic benefits (in 2000 dollars) to commuters by income class and to all non-commercial travelers for 2050 (for the a.m. peak period)

	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	$0.05	$0.89	$0.91	$0.22	$0.49
Medium income commuters	-$0.29	$0.79	$0.64	-$0.66	$0.36
High income commuters	-$0.14	$0.65	$0.42	-$1.12	-$0.35
All non-commerical trips	-$.024	$0.44	$0.26	-$0.16	$0.23

Table 10 adjusts the aggregate welfare measure for 2050 by adding in the full costs of owning a car. The new car cost is 56 cents per mile,[11] 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 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, it is believed 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, and so the long-term costs of the auto mode influence all decisions. Because there is some debate about this, the calculation were performed both ways. This can be done only for all private trips collectively, since VMT for work trips by income group cannot be acquired in MEPLAN. The daily reductions in travel costs would be three-to-four times as large.

Here an indicative, final-year analysis is performed, rather than the more correct cumulative analysis of the stream of discounted net benefits over time. It would be very time-consuming to take the results for each model year and copy them into spreadsheets for these calculations, as the model results are in large text tables. It is also believed that in such long-range scenarios, all projections are very approximate due to inevitable changes in the economy, such as oil prices, housing costs, education levels, labor costs, and so on. It is this research group's belief that our method is sufficient to demonstrate the results in ordinal fashion, with rough magnitudes.

In our past studies, we wrestled with these issues, which include the differential inflation rates for capital for transit and road construction and inflation rates for labor for their operations, and there are no agreed-on methods for projecting these changes. In the Sacramento MEPLAN model, all exogenous costs are assumed to be constant over the 50 years (and are in year 2000 dollars).

It appears that, with the full user cost method, all scenarios are strongly beneficial, except for Scenario 1, which is slightly economically negative. 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 Tables 8 and 9. Again, with this method, the UGB scenarios have even more strongly positive effects on travelers, due to shorter trips. These values are similar in sign and size to those from our earlier studies, using the SACOG travel model on similar policies.

Table 10 Total a.m. peak period and per trip changes, from the Base Case, in 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

The implications of traveler welfare results for the region are significant. When travel costs are reduced, households and firms take the saved income and spend it on other goods and services, most of which are in the region, as mentioned above. So, because the lowered spending on travel is mostly compensated by higher spending on other goods, there is little loss of total demand in the region. In addition, the lower travel costs in the region attract more households and firms to locate there, or to expand their operations, and so the region's growth rate will increase slightly.

These lower travel costs, however, can be offset by higher rents. In the previous subsection, the locational changes in the scenarios were discussed. The model derives rents paid by households and firms from an iterative bidding process, within each zone and among zones. If vacant developable land becomes scarce in a zone, floor space developers charge more per square foot in that zone. This price rise then leads to higher rents per square foot and then to lower space consumption per employee and per household.

The model produced reasonable changes in rents across the scenarios. For example, the three UGB scenarios resulted in regional total rents paid by households rising 20-25 percent, compared to the base case. The ECOS and Pricing scenarios resulted in rents one to two percent higher than the base case. These outcomes are theoretically correct in sign and ordinally reasonable. Since UGB scenarios were not fine-tuned with respect to the land markets in each county (in terms of where the line was drawn, and not allowing any more development of any kind in most of the outer zones), they resulted in a worst-case effect on rents. So, the 20 to 25 percent increase should be viewed as an upper bound.

Any actual regional habitat and agricultural protection plan would certainly leave many rural areas open for development, and so the rent rises would be much lower. In addition, upzoning a small percentage of lands to multifamily residential densities in most zones would further reduce the price rises for lower-income households. The great majority of the other households are homeowners, and consequently take the rent increase as a profit when they sell.

CONCLUSIONS

This study has demonstrated a pair of important points. First, sophisticated, 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 roughly understand and appreciate the model and its abilities and limitations. Second, a model such as MEPLAN can produce reasonable results 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.

This modeling exercise is forecasting travel and land use 50 years into the future. To say that this is ambitious is a bit of an understatement. Much can happen in 50 years that would alter the assumptions of this model. This is particularly true for large disturbances in model parameters. For example, significant changes in the availability and cost of gasoline would produce different travel and land use outcomes than have been represented here. On the other hand, modeling distant time horizons may be beneficial in that many disruptions smooth out over time. For example, the oil embargos of the 1970s dramatically changed travel behavior in the short term, as people drove less.[12] But by the mid-1980s, travel trends picked up where they left off prior to the embargoes.

In terms of the policies analyzed, Scenario 5 is the best in terms of lower emissions and full cost traveler welfare. Scenario 3 was the second best in the full cost analysis. Scenarios 3, 4, and 5 are the only ones that reduce VMT and emissions more than 10 percent in 2025. Scenarios 1 through 5 all have positive effects on low-income travelers, mainly due to improved transit services.

The outputs presented here are of value in that they seem to be reasonable forecasts, given the assumption that the future will be much like today. Of course, these scenarios take on additional value if you believe that oil prices may rise sharply after 2020. They show that transit and UGB policies complement higher fuel prices. As land use patterns change only at the rate of one to three percent per year, local decision makers may wish to plan ahead for an almost certain future of much more expensive fuels. As the incomes of the lower half of California households by income have fallen about 30 percent in the last 20 years, decision makers may also want to serve this large group with less-expensive transport options.

APPENDIX A: TRANSPORTATION IMPROVEMENTS IN SACOG BASE CASE

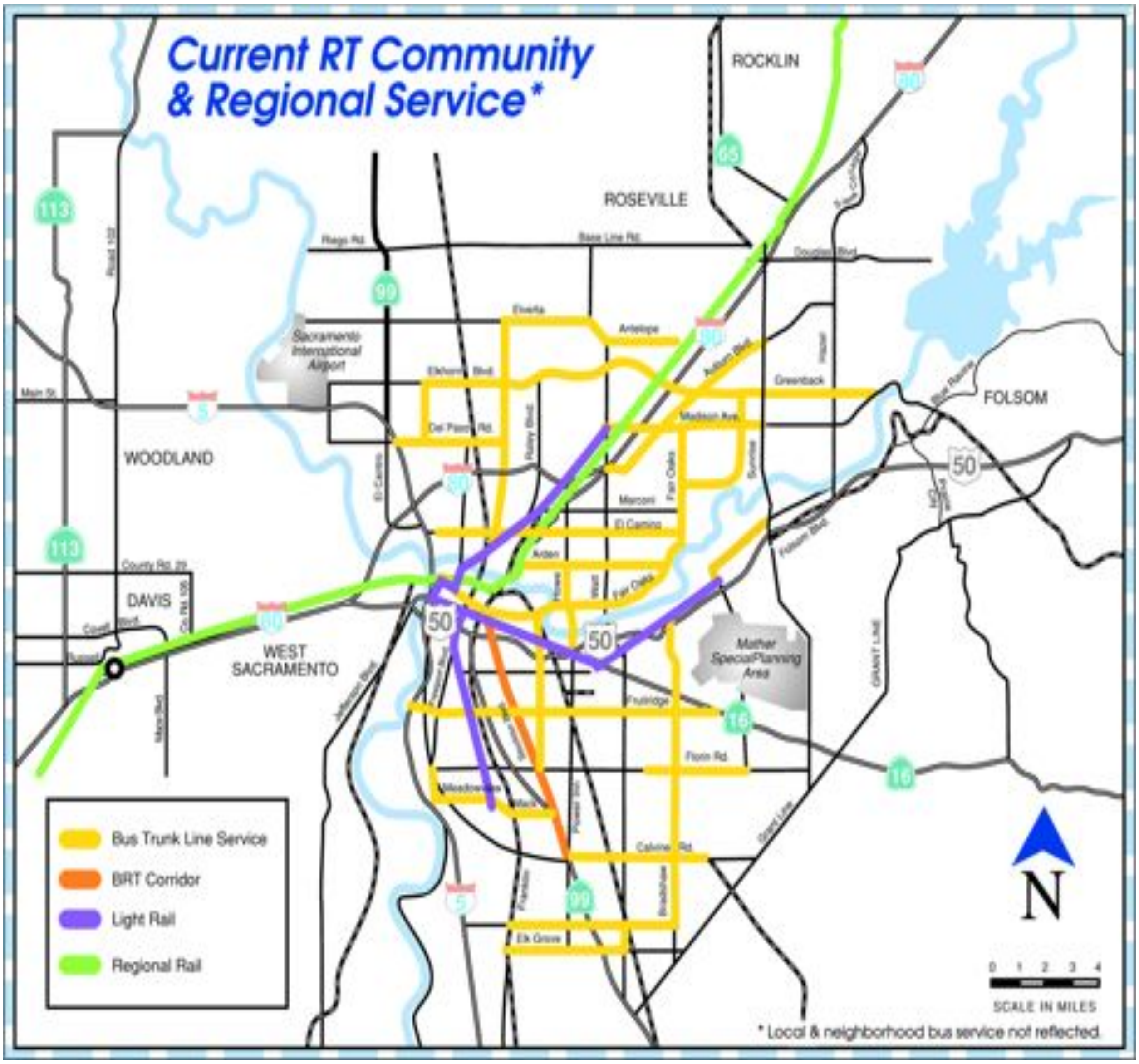

Figure 8 Current Sacramento region transit routes ("Base Case")

MAJOR ROAD PROJECTS

Below is a summary of the major road projects in the Base Case. It is clear that high occupancy vehicles (HOVs—vehicles with multiple occupants) are a strategy embraced by the SACOG Base Case. In 2005 (not discussed here) and 2015, numerous HOV lanes were created or expanded. Improving auto travel in general is clearly an aim of the Base Case scenario as well. As can be seen below, freeways are created and expanded, interchanges are created and improved, rural highways are upgraded to expressways, and two notable projects, the southeast bypass (see 2015 for details) and the Placer Parkway (see 2025) are built.

Major Road Projects Completed by 2015:

- New HOV lanes between West Sacramento and Davis on Interstate 80
- Extension of HOV lanes on Highway 50, west to the Downtown and east to Shingle Springs
- Extension of HOV lanes on Interstate 80 west to the intersection with Highway 99 and east to city of Rocklin
- New HOV lane on Interstate 5 between Highway 50 and Interstate 80
- Roughly 25 new HOV ramp bypasses
- Three new ramps and five expansions of existing ramps on Highway 50
- Conversion of Highway 99 at the section between Highway 99 and Highway 70 to Tudor Road from major arterial to rural experssway (about 5.5 miles)
- Conversion of Highway 70 at the section between Highway 99 and Highway 65 from major arterial to rural expressway (about eight miles)
- Creation of a beltway outside Marysville that connects Highway 65 and Highway 20 (about 6.5 miles)
- Extension of the freeway portion of Highway 65 from where it currently ends to Lincoln (currently a major arterial–about three miles)
- Conversion of a two-lane major arterial into a four-lane expressway outside Lincoln (about 4.6 miles)
- Creation of a southeast bypass, linking Interstate 5, Highway 99 and Highway 50:
    - Conversion of Hood Franklin Road from major arterial to rural expressway between Interstate 5 and Highway 99, and extended to connect with Grant Line Road.

  - Conversion of Grant Line Road and Sunrise Boulevard (southern section from Grant Line Road to Highway 50), from major arterial to a four-lane expressway.
- New expressway from the intersection of Sunrise Boulevard and Folsom Boulevard to the intersection of White Rock Road and Grant Line Road
- Expressway south of Hazel Boulevard to Grant Line Road
- Expansion of Hazel Avenue-Sierra College Boulevard from a four-lane major arterial to a six-lane urban expressway, which connects Highway 50 and Interstate 80

Major Road Projects Completed by 2025:

- Extension of HOV lanes on Interstate 5 north to Sacramento International Airport and south to Laguna Boulevard
- Placer Parkway, which connects Highway 99 and Highway 65

Major Road Projects Completed by 2035:

- New expressway from Sunrise Boulevard at Elverta Road to Placer Parkway
- New HOV lanes from Sacramento International Airport to Woodland
- South extension of South Berver Road from Riego Road to Elverta Road
- Conversion of Highway 16 into an expressway at the section from Folsom Boulevard to Grant Line Road

Major Road Projects Completed by 2050:

- There are only several arterial road projects in non-urbanized areas

MAJOR TRANSIT IMPROVEMENTS

Major Transit Improvements Completed by 2015:

- Twenty-seven new bus lines
- Five new light rail transit (LRT) lines:
  - LRT1 shares the same stations of existing line (LRTX) on I-80 corridor and then goes south to Cosumnes River College, which serves the area between I-5 and Highway 99.

- LRT2 shares the stations of the existing line (LRTX) from Downtown Sacramento to Mather Field/Mill station and then goes east toward Sunrise Boulevard.
- LRTP is the east extension of LRT2 and connects Sunrise Boulevard and the city of Folsom.
- LRTA directly connects Downtown Sacramento and Folsom.
- LRTDNA connects Downtown Sacramento with Sacramento International Airport and serves South Natomas and North Natomas.

- Five new Bus Rapid Transit (BRT) lines:
  - 01BR/02BR runs between Roseville and Mather Field light rail station on Sunrise Boulevard. Its headway is 30 minutes in both peak and non-peak hours.
  - 50BRA/50BRB runs on Florin Road-65th Street-Stockton Boulevard-Broadway to Sacramento Downtown. Its headway is 10 minutes in peak hours and 20 minutes in non-peak hours.
  - 80 BRL/81BR2 serves Watt Avenue corridor at the section between I-80 and Highway 50. Its headway is 30 minutes in both peak and non-peak hours.
  - 80BR1/81BR1 serves the whole Watt Avenue corridor. Its headway is 60 minutes in both peak and non-peak hours.
  - GRBR runs on the Elk Grove Boulevard-Grant Line Road-Sunrise Boulevard (southeast bypass).
  - A BRT line is designed 22 percent slower than a car and nine percent faster than a regular bus.

Major Transit Improvement Completed by 2025:

- Two new standard bus lines

Major Transit Improvements Completed by 2035:

- Two new light rail transit lines:
  - LRTR from Roseville to Marconi/Arcade; and
  - LRTS from Downtown Sacramento to West Sacramento.

Major Transit Improvements Completed by 2050:

- Three new light rail transit lines:
  - LRTCT from LRTX Power Inn Station to Grant Line Road along existing rail line;
  - LRTFED from Folsom LRT to East Folsom; and
  - LRTFO from Mather Field to Greenback Lane along Sunrise Boulevard.

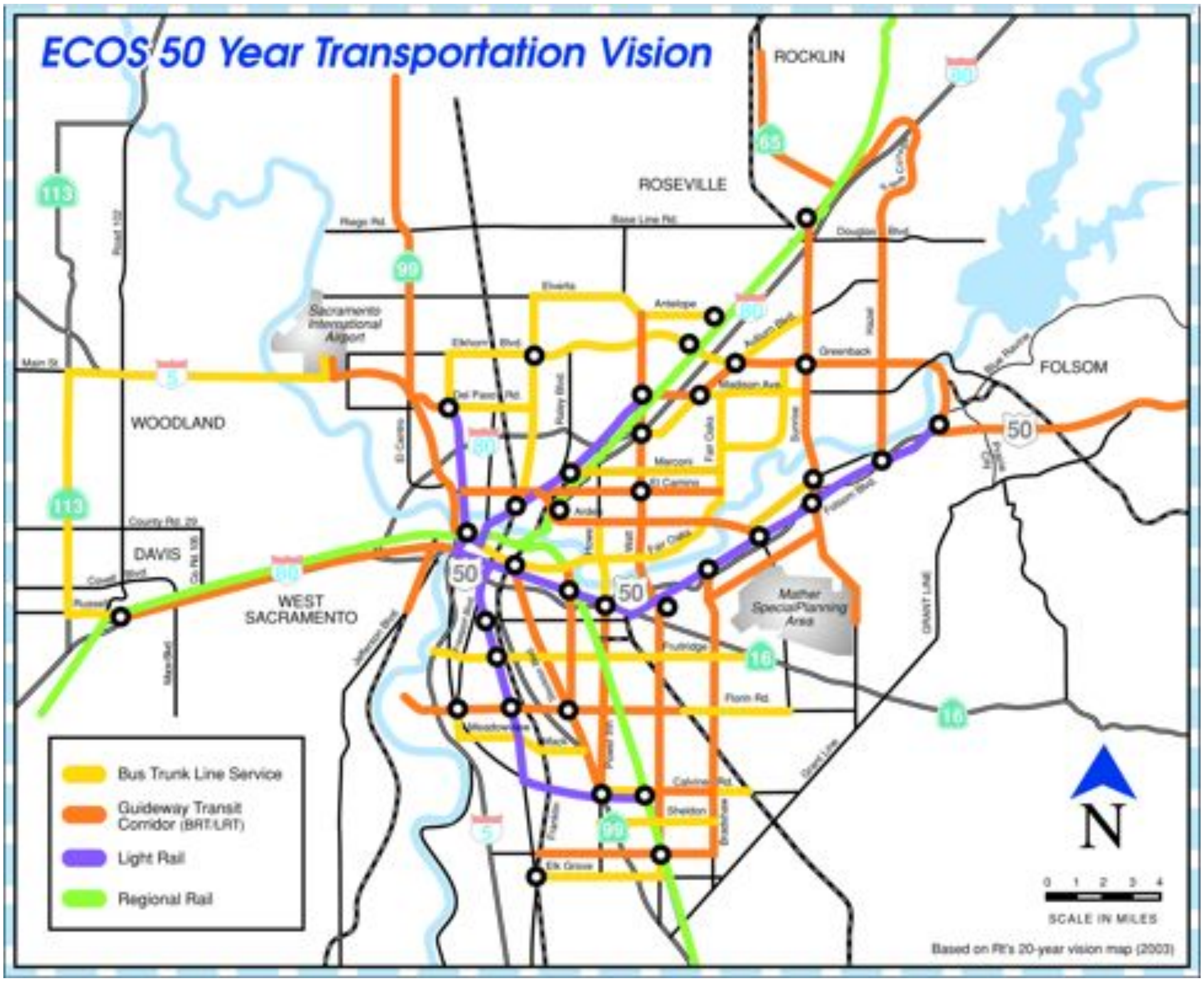

Figure 9 ECOS's 50-year transit-only vision for the Sacramento region

APPENDIX B: MAJOR TRANSIT IMPROVEMENTS DEVELOPED BY COMMUNITY ORGANIZATIONS FOR SCENARIOS 1, 3, 4 AND 5

MAJOR TRANSIT IMPROVEMENTS

Transit Improvements Completed in 2015:

- Carried over from SACOG's Base Case:
    - 01BR/02BR, 50BRA/50BRB, 80BR1/81BR1 and 80BR1/81BR1 are kept from the Base Case but are converted to run in dedicated BRT lanes (see Base Case for for descriptions of these BRT lines)
    - 01BR/02BR is extended south about five miles to Mather military base
    - GRBR BRT line is removed (Grant Line Road)
- New BRT lines:
    - DBR from Davis to West Sacramento
    - YBR from Sacramento Downtown to Yuba City-Marysville
    - OBR on Old Placer Road
    - BBR on Bradshaw Road
    - LBR on Laguna Boulevard-Bond Road
    - PBR on Power Inn Road
    - FBR on Florin Road
    - ABR1/ABR2 on Arden Way
    - EBR on West El Camino Road and El Camino Road
    - TBR from Sacramento Amtrak Station to South Natomas
    - SBR from Roseville to Lincoln on Highway 65
    - ABRA/ABRB from Auburn to Watt light rail station on Interstate 80
    - HBR on Hazel Boulevard
    - MBR from Watt light rail station to city of Folsom primarily on Greenback Lane
- LRT and bus headways remain the same as in the Base Case, ranging from 10 to 90 minutes.

- Link speed for LRT ranges from six 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 likely require grade separation of LRT (underground) in the downtown zones.

Transit Improvements in 2025:

- Headways for LRT, BRT and standard buses were cut by 50 percent.
- Headways for LRT and standard buses now ranged from five to 45 minutes.
- Headways for BRT now dropped to 10 minutes.

Note that a drop in headways requires additional transit vehicles, a major capital expenditure.

Transit Improvements in 2035:

The headways of LRT, BRT and standard buses were all set to 7.5 minutes.

APPENDIX C: EMPLOYMENT CHANGES BY ZONE

Employment difference by zone in 2025

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
1	0.36	35.05	35.57	-6.95	25.99
2	-0.24	7.80	7.54	0.69	4.78
3	0.11	5.15	5.41	-0.73	4.06
4	-0.62	4.63	3.72	-1.66	2.80
5	-0.60	4.07	3.73	-0.90	3.01
6	-1.10	6.49	5.56	-2.19	4.19
7	0.23	10.49	10.34	1.41	11.78
8	-0.25	5.74	5.37	-0.01	5.13
9	2.99	5.67	8.44	2.54	7.61
10	0.95	6.73	7.51	0.61	6.82
11	-1.53	4.70	3.40	-1.72	2.58
12	0.30	7.65	7.09	2.31	10.56
13	-0.61	4.04	3.52	-1.10	2.95
14	0.49	7.79	8.05	1.00	8.00
15	-0.16	3.68	3.21	-0.84	2.09
16	2.30	6.56	8.74	3.55	10.44
17	1.00	25.44	25.53	-1.66	20.46
18	-0.08	17.41	18.34	-2.77	13.26
19	1.18	13.09	14.85	-0.21	12.78
20	-.50	-53.12	-52.79	-2.02	-54.09
21	-0.34	10.80	12.31	-1.81	7.88

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
22	-0.58	-87.89	-88.00	2.76	-88.34
23	-0.82	-55.37	-55.30	-4.00	-56.86
24	0.16	-82.15	-82.35	-0.12	-57.06
25	2.52	-16.10	-14.68	1.07	-16.34
26	-4.78	57.45	41.49	-1.63	48.56
30	0.53	-70.25	-70.02	-2.03	-70.50
31	-1.99	-2.95	-2.37	-2.26	-3.42
32	1.14	-34.07	-32.88	-0.59	-34.09
33	1.34	3.62	6.17	0.41	4.47
34	0.18	-8.09	-5.43	-2.80	-7.35
36	3.66	6.83	9.49	1.61	8.65
40	-0.03	43.32	42.48	-1.54	41.51
41	0.71	3.42	4.29	-3.10	0.64
42	-1.63	-9.30	-8.44	-2.89	-9.97
43	0.28	-65.39	-65.24	1.90	-65.62
44	0.43	53.11	54.20	-2.60	44.56
45	-0.10	4.16	0.14	-2.33	-1.71
46	-1.65	-54.55	-55.22	-1.59	-55.29
47	-1.05	-62.50	-62.79	-1.61	-62.86
50	0.60	8.68	8.75	-0.13	7.06
51	-0.76	13.31	13.15	2.18	16.82
52	-1.67	14.93	13.53	1.14	16.98
53	-0.46	-84.11	-83.97	-1.64	-84.35
54	-3.80	-50.51	-50.47	-4.77	-52.16

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
55	-1.90	-59.92	-60.22	-2.93	-61.61
56	-0.71	-71.59	-71.54	-5.45	-72.86
70	-0.58	4.89	4.83	0.65	6.57
71	-1.47	9.07	8.62	-1.36	8.45
72	-1.53	-67.21	-67.85	-1.53	-68.54
73	-1.16	-98.36	-98.36	-1.49	-98.41
74	-1.64	-92.23	-92.52	-2.58	-92.71
75	0.41	-55.51	-55.14	1.62	-55.58
76	0.16	3.55	4.37	0.24	3.59
77	-0.24	2.07	2.56	-1.55	0.74
78	-0.71	-0.16	0.04	-1.81	-1.43
79	0.08	11.33	11.90	-0.60	10.24
80	0.55	8.08	8.63	0.01	7.26
81	-1.53	-16.88	-16.82	-1.60	-17.30
85	-1.31	13.60	12.48	-2.65	9.49
86	0.27	13.53	13.88	-1.53	11.42
87	3.05	-54.43	-54.25	-4.45	-55.59
88	0.81	7.58	7.37	-4.81	1.67
89	-0.42	-44.79	-45.44	-2.99	-46.54
90	-0.27	5.83	5.48	-2.20	2.94
91	0.29	3.25	3.70	-1.50	1.49
92	2.53	4.31	7.57	1.29	6.05
93	-0.41	-30.74	-31.09	-1.04	-31.54
94	0.05	-32.81	-33.23	-0.52	-34.37

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
95	1.22	-54.96	-54.81	-1.14	-55.96
96	-0.72	-23.08	-23.29	-1.99	-24.92

Employment difference by zone in 2050

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
1	1.13	24.49	25.76	-1.50	28.07
2	12.54	26.13	27.93	16.92	18.22
3	-0.59	7.82	7.62	-1.77	5.07
4	1.30	5.51	6.95	0.12	5.28
5	0.70	6.15	7.01	0.45	5.55
6	2.97	8.66	10.41	1.19	7.49
7	2.76	21.84	26.27	3.71	24.78
8	2.71	9.56	12.84	2.34	11.48
9	5.02	6.79	12.30	4.48	11.00
10	5.14	8.38	13.47	5.17	11.62
11	0.46	5.83	7.10	0.02	4.83
12	7.29	13.19	16.64	8.63	21.64
13	3.62	5.46	8.66	3.23	8.22
14	-0.69	9.70	9.32	-0.41	8.29
15	1.69	3.01	5.27	-0.11	2.74
16	3.40	9.74	13.10	4.10	14.21
17	-3.41	42.71	31.93	-5.05	27.92

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
18	-0.39	24.44	29.02	-2.43	23.85
19	0.91	21.15	22.74	0.03	20.34
20	-1.31	-64.47	-65.42	-4.75	-66.04
21	-6.07	17.90	17.77	-9.47	9.46
22	-3.22	-91.53	-92.74	-2.49	-93.06
23	-2.01	-70.84	-73.82	-9.97	-74.63
24	-5.02	-87.98	-87.98	-6.04	-60.13
25	17.28	-30.59	-27.48	16.87	-28.23
26	-24.77	44.60	7.44	-19.25	13.24
30	-4.25	-84.12	-84.76	-10.16	-85.24
31	3.77	-0.79	1.73	2.07	0.64
32	2.48	-45.55	-44.84	-1.28	-46.31
33	4.20	6.83	9.73	2.45	6.82
34	-4.27	-14.79	-19.35	-9.18	-20.83
36	11.94	8.98	14.89	6.85	15.80
40	2.08	63.97	60.60	-0.57	63.20
41	4.00	4.26	3.24	-3.64	-2.53
42	-2.44	-4.32	-6.96	-4.06	-8.39
43	-0.28	-80.77	-80.72	1.75	-81.12
44	-0.77	64.17	63.75	-7.89	55.94
45	0.41	-0.26	0.52	-2.57	-3.00
46	-1.36	-73.23	-74.20	-1.13	-74.37
47	6.45	-75.87	-75.91	9.76	-76.18
50	-4.52	14.66	9.75	-5.42	7.24

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
51	0.70	25.08	24.21	4.69	28.79
52	-3.43	31.32	29.61	1.33	32.18
53	4.65	-88.83	-89.36	6.52	-89.55
54	-5.95	-62.53	-63.77	-6.30	-65.12
55	-1.50	-71.41	-72.10	-4.05	-73.32
56	-2.17	-82.66	-83.55	-9.03	-84.61
70	-6.82	6.55	-1.99	-4.93	0.03
71	-8.46	6.47	-1.98	-9.77	-1.97
72	-6.67	-79.66	-80.99	-3.39	-81.50
73	-27.67	-99.19	-99.27	-28.27	99.30
74	-22.13	-95.16	-96.73	-25.12	-96.83
75	1.90	-67.79	-67.48	4.00	-68.14
76	1.60	7.87	9.02	1.26	7.70
77	-1.56	3.78	1.59	-2.90	-0.40
78	9.21	3.55	12.01	7.58	5.35
79	1.90	24.03	25.93	-0.15	19.77
80	2.39	14.30	15.61	0.91	13.02
81	0.14	-24.02	-24.22	-0.38	-24.88
85	-1.36	18.94	17.88	-3.32	15.66
86	-2.26	13.17	11.94	-3.96	10.58
87	6.20	-74.30	-73.53	0.87	-74.43
88	-2.49	12.08	11.46	-8.88	2.06
89	-0.02	-60.86	-61.73	-2.93	-62.74
90	-1.23	7.23	6.35	-3.31	3.92

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
91	0.26	4.16	4.07	-2.50	1.36
92	2.90	5.10	8.66	0.33	5.65
93	-3.97	-46.09	-47.67	-5.63	-48.18
94	0.49	-51.86	-51.92	-1.26	-52.84
95	-0.22	-69.81	-70.18	-0.59	-71.12
96	18.75	-33.92	-22.61	18.53	-24.67

APPENDIX D: HOUSEHOLD CHANGES BY ZONE

Household difference by zone in 2025

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
1	-3.19	63.38	59.25	-14.08	40.20
2	0.09	12.31	12.20	-1.56	9.09
3	-0.16	6.89	6.64	0.91	7.28
4	0.07	7.89	7.86	1.68	9.39
5	0.59	8.50	9.09	1.91	10.26
6	0.24	19.21	19.61	1.20	20.09
7	0.38	13.62	13.88	1.09	13.47
8	0.06	8.11	8.07	2.17	10.08
9	1.08	6.27	7.42	3.40	9.45
10	-0.04	7.11	6.99	1.39	7.97
11	0.27	9.28	9.48	2.36	11.57
12	0.62	20.89	21.67	5.11	28.69
13	0.04	7.06	6.88	2.36	9.04
14	0.35	9.88	10.00	2.80	12.14
15	-0.28	5.89	5.71	2.76	7.79
16	0.98	8.30	9.16	1.90	9.96
17	1.20	34.69	36.48	0.09	31.08
18	0.64	24.54	24.84	1.22	23.95
19	1.20	22.14	23.05	2.07	22.99
20	0.31	-69.32	-69.34	-8.14	-70.28
21	0.12	16.04	16.05	-3.64	10.42

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
22	0.09	-91.63	-91.63	-4.22	-91.86
23	0.13	-49.76	-49.85	-6.62	-51.28
24	-0.34	-86.25	-86.24	-0.54	-86.77
25	0.61	-2.37	-1.98	1.72	-1.30
26	-0.60	65.42	61.10	-8.49	44.83
30	-1.17	-86.29	-86.31	-8.47	-86.70
31	-1.18	3.85	3.85	-2.77	1.32
32	-0.09	-24.73	-24.22	-5.28	-26.57
33	-0.14	-20.11	-19.76	-4.42	-22.54
34	-0.93	7.53	7.94	-2.69	5.50
36	1.05	16.94	18.08	4.47	21.44
40	-1.19	70.94	70.18	-8.08	49.65
41	-0.82	17.28	17.45	1.42	18.38
42	-0.82	30.88	31.06	0.29	29.64
43	-1.25	-72.75	-72.75	-5.38	-73.22
44	-1.26	38.00	37.84	-5.25	27.51
45	-0.67	12.06	11.46	4.07	15.47
46	-1.91	-56.99	-56.96	-5.71	-57.54
47	-1.42	-39.20	-39.06	-6.29	-40.30
50	0.34	29.83	30.26	16.21	51.01
51	0.14	29.20	29.04	3.37	32.96
52	0.32	24.50	29.04	3.37	32.96
53	0.55	-95.14	-95.15	-8.97	-95.29
54	-0.76	-44.16	-44.19	-6.13	-45.29

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
55	-0.73	-68.05	-68.08	-7.96	-69.11
56	-0.52	-87.24	-87.24	-10.18	-87.62
70	0.36	14.33	14.57	2.35	17.15
71	0.25	36.26	36.54	1.94	38.31
72	1.07	-74.01	-73.73	-0.94	-73.47
73	-0.25	-98.05	-98.05	-6.70	-98.10
74	-3.07	-94.55	-94.59	-6.15	-94.72
75	0.27	-54.25	-54.28	3.83	-53.64
76	1.65	19.44	20.39	3.87	22.37
77	0.31	22.35	22.61	-0.84	20.21
78	0.20	10.02	10.29	-0.69	8.75
79	-1.19	24.81	24.71	-5.02	19.63
80	-0.04	5.92	5.83	-4.17	0.32
81	0.33	-33.05	-32.99	0.10	-33.02
85	0.26	32.03	32.99	-1.48	27.95
86	-1.56	29.14	27.74	-4.34	21.52
87	-0.78	-41.85	-41.88	-4.92	-43.42
88	-1.01	20.30	19.54	-4.64	13.05
89	-1.35	-43.33	-43.60	-5.51	-44.92
90	-1.21	19.38	17.89	2.45	21.92
91	2.45	21.41	23.20	7.23	27.44
92	1.68	17.51	18.58	9.60	28.93
93	-0.71	-21.30	-21.52	-3.52	-23.15
94	-1.01	-41.14	-41.42	-5.02	-42.98

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
95	-1.20	-48.79	-48.93	-5.52	-50.48
96	-1.33	-38.01	-38.35	-5.44	-40.33

Household difference by zone in 2050

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
1	-1.57	42.15	39.33	-7.52	31.69
2	2.16	24.89	25.41	2.66	23.25
3	0.61	9.83	10.04	1.93	10.54
4	0.82	10.00	10.14	2.59	11.66
5	1.05	11.33	12.02	3.26	13.72
6	3.24	24.01	26.27	5.17	27.87
7	1.98	24.10	25.51	2.74	23.91
8	1.18	14.01	14.62	3.55	16.52
9	1.39	8.74	9.68	3.31	10.96
10	1.14	9.82	10.38	4.08	12.26
11	0.58	12.03	12.17	2.75	13.62
12	3.24	36.70	39.73	11.13	49.48
13	1.06	8.84	9.45	3.64	11.60
14	0.80	11.20	11.58	1.72	11.72
15	0.80	7.68	8.09	3.39	9.54
16	1.41	12.72	13.72	2.41	14.23
17	2.96	71.25	74.17	2.06	62.47

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
18	1.76	34.98	37.21	4.25	38.40
19	1.64	34.25	36.26	2.99	34.83
20	-0.77	-80.01	-80.14	11.35	-80.69
21	-0.42	25.90	26.21	-5.06	17.44
22	-6.22	-94.71	-94.84	-11.89	-95.02
23	-1.06	-64.81	-65.05	-9.26	-66.20
24	2.33	-88.70	-88.72	0.73	-89.25
25	2.23	-7.37	-6.60	-6.78	-4.41
26	-10.16	74.70	44.89	-17.47	31.80
30	-4.59	-91.19	-91.27	-12.51	-91.50
31	0.10	5.63	6.28	-1.22	4.06
32	2.50	-34.98	-34.53	-5.15	-36.36
33	3.74	-25.80	-24.73	-3.33	-27.78
34	0.51	11.36	10.85	-1.71	8.39
36	2.23	22.74	23.25	5.38	26.13
40	-0.87	94.70	92.21	-9.54	71.04
41	-0.38	24.51	24.18	1.48	25.70
42	0.28	37.05	36.51	1.88	36.00
43	-2.78	-82.51	-82.49	-10.99	-82.82
44	-5.43	94.00	81.54	-10.99	61.36
45	1.39	15.16	16.51	5.99	19.66
46	-0.77	-68.73	-68.65	-4.55	-69.08
47	-0.01	-52.50	-52.58	-5.27	-53.49
50	1.45	38.37	38.64	14.72	50.28

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
51	2.55	48.56	51.08	10.35	59.63
52	1.37	38.78	39.97	7.27	42.22
53	3.59	-96.93	-96.93	-6.32	-97.02
54	-1.15	-58.41	-58.53	-6.52	-69.29
55	-1.48	-77.77	-77.92	-11.02	-78.74
56	-1.25	-92.07	-92.14	-15.40	-92.40
70	2.04	22.19	23.73	4.65	26.08
71	3.28	47.38	49.78	3.88	48.64
72	2.17	-83.56	-83.39	1.34	-83.15
73	-9.23	-98.84	-98.85	-13.77	-98.88
74	-18.15	-96.97	97.03	-20.89	-97.11
75	3.69	-69.25	-67.92	6.95	-67.53
76	3.35	26.52	28.63	6.37	29.73
77	2.50	34.92	36.41	1.52	33.55
78	2.01	14.40	16.19	2.70	16.51
79	4.69	37.78	43.38	0.68	37.08
80	0.67	11.57	11.76	-5.09	2.58
81	2.22	-46.73	-46.08	1.82	-46.21
85	3.18	44.25	46.08	-0.90	37.97
86	-0.82	32.03	46.08	-0.90	25.27
87	0.22	-58.52	-58.56	-5.00	-59.71
88	-0.59	32.26	30.10	-5.95	20.16
89	-0.59	-58.51	-58.74	-5.30	-59.57
90	0.01	29.97	29.27	3.81	32.58

Zone	Scenario 1: Transit Improvement	Scenario 2: UGB	Scenario 3: Transit with UGB	Scenario 4: Transit with Pricing	Scenario 5: Transit with UGB and Pricing
91	5.71	34.37	37.41	11.66	41.42
92	3.94	29.22	30.72	13.00	41.01
93	-0.01	-34.00	-34.23	-2.46	-35.20
94	-0.35	-56.07	-56.27	-5.20	-57.42
95	-1.33	-63.79	-64.15	-6.21	-65.24
96	5.34	-52.12	-50.41	-0.06	-51.96

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ABBREVIATIONS AND ACRONYMS

BRT	Bus Rapid Transit
CBD	Central Business District
CV	Compensating Variation
ECOS	Environmental Council of Sacramento
GIS	Geographic Information System
HOV	High occupancy vehicle
LRT	Light rail transit
MEPLAN	Multi-purpose softward package developed by Marical Echenique & Partners Ltd. in 1984
MPOs	Metropolitan Planning Organizations
NEPA	National Environmental Protection Act
SACOG	Sacramento Area Council of Governments
SAC-TE	Sacramentans for Transportation Equity
SAM	Social accounting matrix
SOV	Single occupancy vehicle
SUV	Sport utility vehicle
UGB	Urban Growth Boundary
VMT	Vehicle miles traveled

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