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MTI Report 01-08

Norman Y. Mineta
International Institute for
Surface Transportation Policy Studies
Created by Congress in 1991

Applying an Integrated Model to the Evaluation of Travel Demand Management Policies in the Sacramento Region: Year Two

Mineta Transportation Institute
San José State University
San Jose, CA 95192-0219

MTI REPORT 01-08

Applying an Integrated Model to the Evaluation of Travel Demand Management Policies in the Sacramento Region: Year Two

SEPTEMBER 2001

Robert A. Johnston
Caroline J. Rodier
John E. Abraham
John Douglas Hunt

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16. Abstract

In this study, the authors apply an integrated land use and transportation model, the Sacramento MEPLAN model, to evaluate transit investment alternatives combines with supportive land use policies and pricing policies in the Sacramento region. The current study builds upon the year-one study (Johnson et. al., 2000) in two important respects. First, the study employs a second version of the Sacramento MEPLAN model that explicitly represents floorspace consumption in the land use component of the model. Second, the transit, land use and pricing policies evaluated in the year-two project as expanded and refined in this study in response to the recommendations of local interest groups and the results of the year-one report. Finally, the evaluation of the scenarios is expanded to include total benefit and equity measures.

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EXECUTIVE SUMMARY

In this study, we apply an integrated land use and transportation model, the Sacramento MEPLAN model, to evaluate transit investment alternatives combined with supportive land use policies and pricing polices in the Sacramento region. Highway investment alternatives are simulated as well for purposes of comparison. The application of the Sacramento MEPLAN model is relatively advanced because the model represents a number of induced travel effects, including land use, destination, mode choice, and route choices. As mentioned previously, most analytical tools used to evaluate transportation policies do not represent induced travel effects. State-of-the-practice tools may represent destination, mode choice, and route choice induced travel effects, but land use effects, which may be significant, are very rarely examined.

The current study builds upon the year-one study (Johnston et al., 2000) in two important respects. First, this study employs a second version of the Sacramento MEPLAN model (SacMEPLAN2) that explicitly represents floorspace consumption in the land use component of the model. As described in our year-one report, the absence of a floorspace model in the Sacramento MEPLAN model (version one) tended to over-represent employment location changes in the nearer term (i.e., 20-year time horizon). Second, the transit, land use, and pricing policies evaluated in the year-two project are expanded and refined in this study in response to recommendations of local interest groups and the results of the year-one report. Third, the evaluation of the scenarios is expanded to include total benefit and equity measures.

A number of conclusions can be made based on the results of this case study.

(1) Transportation investment in both highway and light rail may allow for greater decentralization of regional development. Land use and pricing policies may be used to “tame” the decentralizing effects of transportation investments.

(2) New highway capacity projects, even if they include HOV lanes, may increase VMT and emissions.

(3) Transit investment with supportive land use policies and/or pricing policies may be very effective in reducing VMT and emissions.

(4) Transit investment with supportive land use and/or pricing policies may provide congestion reduction that is as great, if not greater, than highway investment policies.

(5) The highway investment policies may, however, provide the greatest level of benefit (i.e., changes in travel time and cost from the base case) compared to transit with and without supportive land use, and/or pricing scenarios.

(6) Equity measures are useful to identify possible disparities in the benefits that may result for the location of transportation investments and policies that may result in losses to certain groups.

INTRODUCTION

To address roadway congestion problems, communities both in California and throughout the nation are proposing major and costly beltway highway projects. Just a few of these projects include Route 710 in California ($310 million per mile), the Grand Parkway in Houston, Texas, and the Legacy Highway in the Salt Lake region of Utah. These projects may also worsen community air quality problems.

The common methods used to evaluate the effectiveness of these highway projects are commonly deficient because they do not represent induced travel effects—how an increase in roadway supply will lower auto travel time costs and increase travel demand. Induced travel effects that can be represented in advanced methods include changes in land use patterns, number of trips made, and destination of trips, choice of travel time, choice of travel mode, and choice of travel route. As a result of their failure to represent induced travel effects, agencies' tools will tend to overestimate congestion reduction and underestimate emissions and air quality problems resulting from new highway projects.

Moreover, the environmental impact statements used to evaluate the environmental impacts and the effectiveness of proposed new highway projects commonly do not adequately identify and evaluate alternatives to highway projects. The literature suggests that alternatives such as transit investments combined with supportive land use policies and/or pricing policies may be just as, or more, effective in reducing congestion and may have the added benefit of improving air quality and protecting environmentally sensitive areas (see literature review below). It is also important to note that even if these alternatives were considered in an environmental impact statement, the evaluation may be biased or inadequate with commonly applied analytical tools. This is because they do not represent induced travel effects and poorly represent transit, walk, and bike modes of travel.

In this study, we apply an integrated land use and transportation model, the Sacramento MEPLAN model, to evaluate transit investment alternatives combined with supportive land use policies and pricing polices in the Sacramento region. Highway investment alternatives are simulated as well for purposes of comparison. The application of the Sacramento MEPLAN model is relatively advanced because the model represents a number of induced travel effects including land use, destination, mode choice, and route choices. As mentioned previously, most analytical tools used to evaluate transportation policies do not represents induced travel effects. State-of-the-practice tools may represent destination, mode choice, and route choice induced travel effects, but land use effects, which may be significant, are very rarely examined.

The current study builds upon the year-one study (Johnston et al., 2000) in two important respects. First, this study employs a second version of the Sacramento MEPLAN model (SacMEPLAN2) that explicitly represents floorspace consumption in the land use component of the model. As described in our year-one report, the absence of a floorspace model in the Sacramento MEPLAN model (version one) tended to over-represent employment location changes in the nearer term (i.e., 20-year time horizon). Previously, the representation of land use changes was catastrophic, but with the new floorspace model, land use changes are path-dependent. As a result, the model now produces a series of real estate changes that can be reviewed for economic reasonability. Second, the transit, land use, and pricing policies evaluated in the year-two project are expanded and refined in this study in response to recommendations of local interest groups and the results of the year-one report. Third, the evaluation of the scenarios is expanded to include total benefit and equity measures.

LITERATURE REVIEW

Modeling studies that have employed advanced analytical tools to simulate transit investment accompanied by land use intensification policies and/or auto pricing policies, indicate that such policies may be more effective than highway investment in reducing congestion. Two recent case studies in the U.S. apply state-of-the-practice regional travel demand models, which represent the destination, mode, and route choice induced travel effects, to simulate such policies. The study in the Sacramento, California region indicated that vehicle hours of delay could be reduced by 13.3 percent for the transit alternative with land use measures and auto pricing policies, compared to 5.2 percent for the highway alternative (Johnston et al., 2000). A simulation study in the Portland, Oregon region indicated that vehicle hours of delay could be reduced by 65.9 percent in the transit investment alternative with land use measures only, compared to 43% for the highway alternatives (CSI, 1996).

These case studies also indicate that highway alternatives will increase VMT and vehicle emissions and that the transit alternative will decrease VMT and emissions, relative to a no-build alternative. For example, the Sacramento simulation study found that the transit alternatives reduced VMT and emissions from approximately 0.2 to 8.8 percent, and that the highway alternative increased VMT and emission from approximately 1.3 to 3 percent. The Portland study found that the transit alternatives would decrease VMT by 0.4 to 6.4 percent and NOx by 2.6 to 8.4 percent and that the highway alternative would increase VMT by 1.6 percent and NOx by 6.7 percent.

The results of these studies are limited to their regions, but they are suggestive of results that might be obtained by other regions that employ advanced analytical tools and seriously evaluate transit alternatives and compare them to proposed highway alternatives in environmental impact statements.

METHODS

THE SACRAMENTO MEPLAN MODEL

The MEPLAN modeling framework is described in Hunt and Echenique (1993). The basis of the framework is the interaction between two parallel markets—the land market and the transportation market. This interaction is illustrated in Figure 1. Behavior in these two markets is in response to price 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.

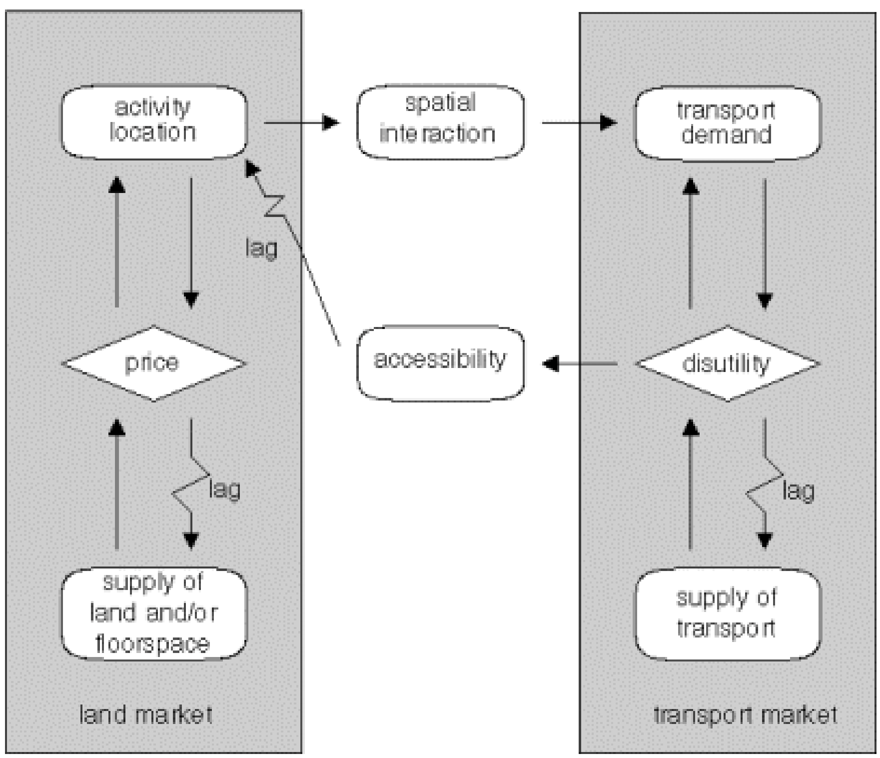


Figure 1. The interaction of the land use and transportation markets in MEPLAN.

The cornerstone of the land market model is a spatially disaggregated social accounting matrix (SAM) (Pyatt and Thorbecke 1976) or input-output table (Leontieff 1941) that is expanded to include variable technical coefficients and uses different categories of space (e.g., different types of building and/or land). Logit models (McFadden 1974) of location choice are used to allocate volumes of activities in the different sectors of the SAM to geographic zones. 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 (Williams 1977) for the mode choice models and stochastic user equilibrium for the traffic assignment model (with capacity restraint). 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” (Meyer and Miller 1984). In a given time period, the land market model is run first, followed by the transportation market model, and then an incremental model simulates changes in the next time period. The transportation costs arising in one period are fed into the land market model in the next time period, thereby introducing lags in the location response to transport conditions. See Hunt (1994) or Hunt and Echenique (1993) for descriptions of the mathematical forms used in MEPLAN.

The specific structure of the Sacramento MEPLAN model is shown in the diagram in Figure 2, and Table 1 defines the categories in the diagram. The large matrix in the middle of the diagram lists the factors in the land use sub model 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).

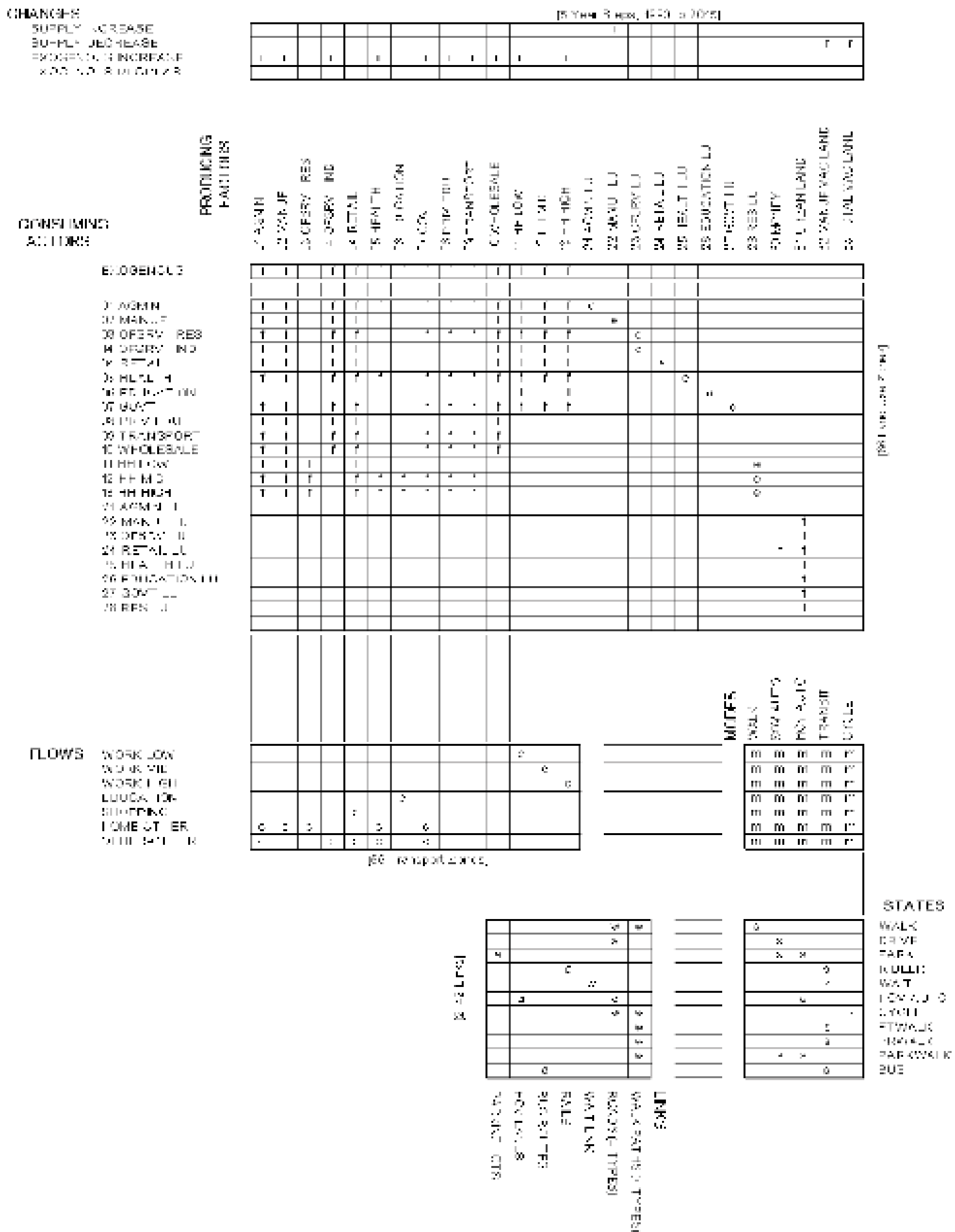


Figure 2. Diagram of the Sacramento MEPLAN Model

Table 1. Description of categories in Figure 2.

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
	HHMID	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

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. 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 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.

The land use component of the Sacramento MEPLAN model was refined in this study to include a floor space sub model allowing for integration with the UPLAN GIS-based urban model. The UPLAN model had different land use types than the original Sacramento MEPLAN model (described above). The land use categorizations were redesigned to match those of the UPLAN model. See Table 2 below.

Table 2. Zoning system for the enhanced Sacramento MEPLAN model. Shading indicates permitted uses. 'x' indicates uses that are theoretically permitted but do not occur in the base data.

Land zoning designation by planner	Space developed by developer						
	Vacant	Industrial	Commercial High Density	Commercial Low Density	Residential High Density	Residential Med Density	Residential Low Density
Industrial	(shaded)	(shaded)	(shaded)	(shaded)	(shaded)	(shaded)	x
Commercial High Density	(shaded)		(shaded)	(shaded)	(shaded)	(shaded)	x
Commercial Low Density	(shaded)			(shaded)	(shaded)	(shaded)	x
Residential High Density	(shaded)				(shaded)	(shaded)	(shaded)
Residential Med Density	(shaded)					(shaded)	(shaded)
Residential Low Density	(shaded)						(shaded)
Urban Reserve							
Agriculture							

In the MEPLAN implementation, each column and row of Table 2 is a MEPLAN factor. The development type factors (the columns in the table) are directly consumed by activities. The factors representing land use planning designations (the rows in the table) are consumed by the development type factors. The consumption rates represent the type of development in each zone, and so are unique for each zone. These consumption rates are manipulated by custom software, written in the Java programming language using the MEPLAN file manipulation library from Abraham, 2000. This custom program is run between each time step and will model redevelopment and demolition as one process and new construction as another process.

The redevelopment and demolition model is a logit model of the choice between first, redeveloping into a different development type; second, demolishing into a “vacant” type; or third, retaining the same type.

The new construction model, also a logit model, represents the choice of what to do with vacant land. Vacant land includes, in each time step, land previously categorized as “urban reserve” or “agricultural” but released for development as policy. The choice is between the different types of allowable development and the choice to leave the land vacant for another time period.

In both of these sub models, the utility for each option is a function of

- The average price per unit for each space development type in the zone, representing the tendency of developers to be attracted to zones and development types where existing rents are high;
- The average price per unit for each space development type in the entire region, representing that the total resources available for development are constrained and each zone has to compete with the region as a whole for development; and
- The average amount of space per employee or household compared to some reference average for the entire region, representing the tendency of developers to respond to vacancy rates.

The calibration used the data for the amount of land in each zone in each time period. The parameters of the development and redevelopment/demolition models used standard “rule-of-thumb” coefficients. We continue to work on obtaining better data on development and plan to conduct a peer review to improve the calibration of the floor space submodel.

The single-row matrix (just above the large matrix in Figure 2) 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.

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 in Figure 2 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 (DKS Associates, 1994). A more detailed description of the Sacramento MEPLAN model design can be found in Abraham (2000).

EMISSIONS MODEL

The California Department of Transportation's Direct Travel Impact Model 2 (DTIM2) emissions model and the California Air Resources Board’s EMFAC7F emissions factors are used in the emission analysis. The outputs from the MEPLAN model used in the emissions analysis include the results of assignment for each trip purpose by each time period (AM peak, PM peak, and off-peak). The Sacramento Area Council of Governments (SACOG) provides regional cold-start and hot-start coefficients for each hour in a 24-hour summer period.

EQUITY AND TOTAL BENEFIT MEASURES

Transportation agencies in the U.S. typically use criteria such as lane-miles of congestion, hours of travel delay, VMT, and mode share to evaluate proposed transportation policies. Such criteria are limited because they fail to account for the balance of effects on travel time and cost from changes in transportation policies. Benefit measures that capture the change in travel time and cost for all modes that may result from a policy scenario can be used to measure gains or losses to specific groups (usually income groups) or the region as a whole.

In this study, we apply the well-known “rule of a half” formula to results of the scenario simulations with the Sacramento MEPLAN model:

$$Benefit \quad Measure = \sum_{m \in M} [(C^{m(p^0)} - C^{m(p^f)})(Q^{m(p^0)} + Q^{m(p^f)})/2]$$

where Cm is the travel time and cost for each mode (m), Qm represents total passenger miles for each mode, p0 indicates the initial point (i.e., before the policy change), and pf indicates the final point (i.e., after the policy change). More specifically, this formula is applied to the results of the home based work trip purpose, which is broken out by three income classes for the a.m. peak hour only. The benefit measure captures changes in travel time and perceived travel costs by mode, but not changes in other externalities and capital, operation, and maintenance costs. Values of in- and out-of-vehicle travel time by income classes were obtained from model parameters. The auto pricing charges in the scenarios are included in the benefit results (i.e., no portion of these costs is assumed to be returned to the travelers). The figures are in 1990 dollars.

SCENARIOS

The selection of scenarios in this study was influenced by local interest group preferences and the results of the year one-study.

We organized and attended meetings with local interest groups to identify scenarios for simulation with the Sacramento MEPLAN model. These groups included ECOS, an environmental umbrella group, and SAC-TE, an umbrella group of neighborhood and social equity groups. The interest groups wanted to examine the following types of scenarios alone and in combination: transit investment, auto pricing policies (i.e., region-wide parking charges and VMT/ fuel tax), and land use policies (i.e., urban growth boundaries, conservation zones for environmentally sensitive lands, and infill development policies).

The results of the year-one study indicated that taxes on outlying development and subsidy policies that tended to increase densities near transit stations may not be enough to generate sufficient densities without strict growth controls elsewhere in the region. It was also found that parking pricing policies near transit stations may be a disincentive to employment location in these areas and thus may reduce the effectiveness of the policies.

To help evaluate the effectiveness of the transit-oriented policies in terms of congestion reduction and air quality, we wanted to compare these scenarios to highway-oriented scenarios.

We examine 10 transportation scenarios in the year 2020. All the transportation network improvements are made in the year 2005 for the scenarios, and thus land uses are affected in the years 2010, 2015, and 2020.

BASE CASE

The base case scenario represents a financially conservative expansion of the Sacramento region's transportation system and serves as a point of comparison for the other scenarios examined in this study. This scenario includes a relatively modest number of road-widening projects and new major roads, one freeway HOV lane segment, and a limited extension of light rail.

HIGH OCCUPANCY VEHICLE LANES (HOV)

The HOV lane scenario represents an extensive expansion of the Sacramento region's HOV lane system. See Figure 3. HOV lanes are increased from 26 lane miles in the base case scenario to 179 lane miles. Mixed-flow freeway lanes are increased by 6 percent compared to the base case scenarios.

BELTWAY

This scenario adds two regional beltways (in the north and south in the east areas of the region) to the HOV lane scenario described above. See Figure 3. This scenario includes 591 new lane-miles of highway, six new interchanges for beltways, 65 lane-miles of new arterial roads to serve the beltways, and 153 lane miles of new HOV lanes.

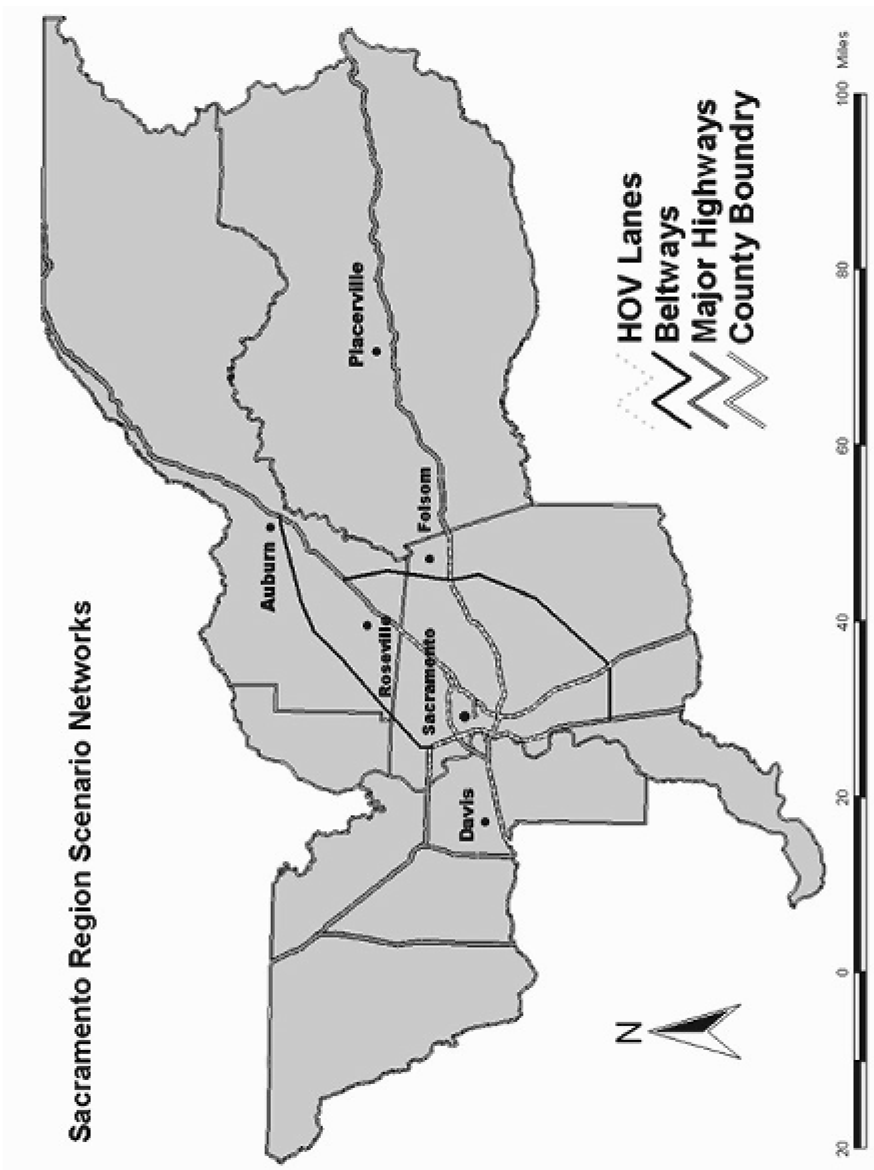
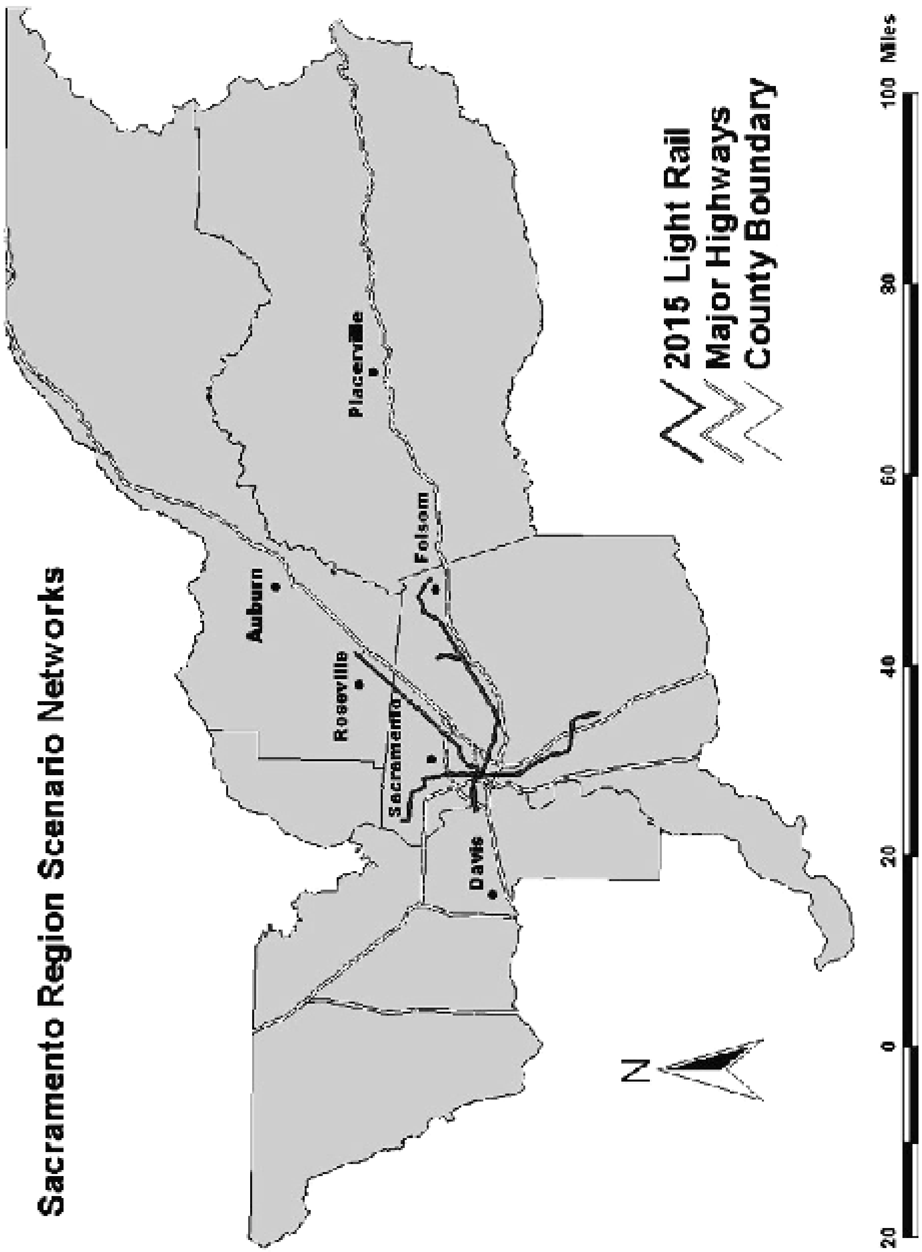


Figure 3. Map of the HOV and beltway networks.

Figure 4. Map of the LRT network.



LIGHT RAIL TRANSIT (LRT)

In this scenario, approximately 75 new track miles of light rail are added to the existing 18 miles of light rail. See Figure 4. This light rail network is combined with advanced transit information systems (ATIS) and local paratransit service. The value of wait time is reduced by a factor of three to represent ATIS, and the access time to transit in areas around transit stations is reduced by 3 minutes to represent paratransit service.

PRICING

The pricing policies include a $0.05 increase in the per mile cost of operating a private vehicle (which simulates a VMT or fuel tax) and a region-wide parking charge that represents an average surcharge of $2 for work trips and $1 for other trips. A $0.05 VMT tax for the Sacramento region is obtained from the low end of the average national estimates of the external costs of auto use (Delucchi, 1997). The pricing policies are implemented in the year 1995.

PRICING AND LRT

This scenario combines the pricing scenario with the LRT scenario.

URBAN RESERVE, INFILL SUBSIDY, AND LRT

This scenario reflects an effort to protect important native habitats in the region and promote more intense growth in the areas around transit stations. Development on vacant, residential, low-density land was restricted in order to protect important habitats. Table 3 documents these restrictions. A land subsidy of 20 percent of expenditures in the year 2000 on land rent was imposed in the zones around transit stations. This scenario also includes the transit service in the LRT scenarios. The urban reserve and infill subsidy policies take effect in the year 2000.

Table 3. Documentation of acres of residential low vacant land used in the urban reserve scenario.

RAD	DESCRIPTION	ACRES OF DEVELOPABLE RESIDENTIAL LOW VACANT LAND		
1	North Natomas	Total in 1990	Habitat Preservation	Total in scenario
2	Rio Linda	259	126	133
3	North Highlands	6,228	4,675	1,553
4	Citrus Heights	397	264	132
5	Orangevale	4	0	4
6	Folsom	1,903	828	1,075
7	South Natomas	1	0	1
8	N Sacramento	0	0	0
9	Arden Arcada	198	178	20

10	Carmichael	0	0	0
11	Fair Oaks	0	0	0
12	Rancho Cordova	64	17	46
13	Downtown	0	0	0
14	Parkpocket	0	0	0
15	E Sacramento	69	27	42
16	S Sacramento	0	0	0
17	Vineyard	458	346	112
18	Franklin L	2,396	2,286	110
19	Elk Grove	425	371	54
20	Delta	4,951	4,581	370
21	Galt	86	79	7
22	Cosumnes	2,425	2,029	396
23	SE County	11,602	10,509	1,093
24	Rancho Murieta	8,246	7,828	418
25	Antelope	0	0	0
30	South Sutter	755	561	194
50	W Sacramento	646	255	391
51	Woodland	0	0	0
52	Davis	46	40	7
53	Clarksburg	0	0	0
54	Esparto/Ca	0	0	0
55	Winters	14	12	2
56	NoName	0	0	0
70	Roseville	0	0	0
71	Rocklin	2,002	1,515	487
72	Lincoln	241	193	48
73	W Placer	2,767	2,587	180
74	Sheridan	289	210	79
75	N Auburn	1,741	1,552	190
76	Auburn	11,953	10,114	1,839
77	Loomis	14,019	11,965	2,054
78	Granite Bay	14,805	12,721	2,084
79	Foresthill	7823	6,163	1,661
80	Colfax	10,204	9,370	834
81	Placer High	17,338	15,501	1,838
85	El Dorado	10,787	9,728	1,058
86	Cameron Park	25,383	22,180	3,204
87	Pilot Hill	6,808	6,370	438
88	Coloma Lot	18,018	17,312	706
89	Diamond Springs	16,546	14,742	1,804
90	W Placerville	28,097	26,976	1,121
91	S Placerville	2,710	2,268	441
92	E Placerville	819	776	43
93	Pollock Pines	4,753	4,176	577
94	Grizzly Flats	9,684	7,460	2,224
95	Georgetown	32,638	31,918	720
96	High Country	34,187	31,342	2,845

PRICING, URBAN RESERVE, INFILL SUBSIDY, AND LRT

This scenario combines the pricing scenario and the urban reserve, infill subsidy, and LRT scenario.

URBAN GROWTH BOUNDARY (UGB) AND LRT

Figure 5 illustrates the zones in this scenario that are designated as no-growth and slow-growth areas of the region. This scenario also includes the transit service in the LRT scenario. These designations are based on environmental considerations and are also intended to support the use of the light rail. In the no-growth zones, development of all vacant land is disallowed. In the slow growth scenarios, development is allowed on only half of the available vacant land. The UGB takes effect in the year 2000.

PRICING, URBAN GROWTH BOUNDARY, AND LRT

This scenario combines the urban growth boundary and the pricing scenarios.

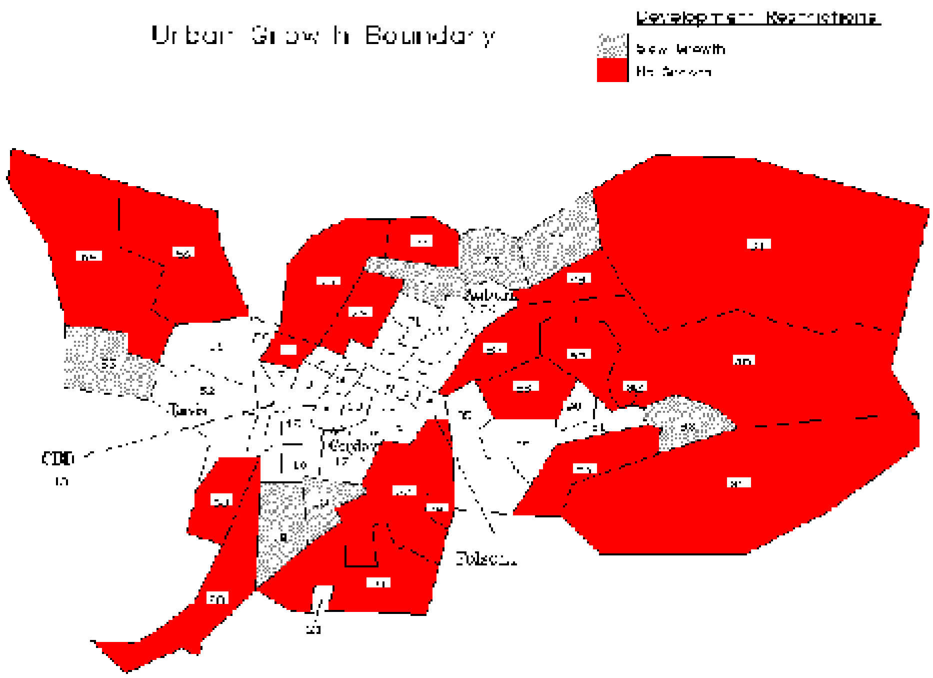


Figure 5. Map of the urban growth boundary.

RESULTS

LAND USE

In the base case scenario, land development from 1990 to 2020 occurs north, east, and south of the City of Sacramento. There is limited land development in the west (Yolo County) because of exclusive agricultural zoning in the county. Over time for the 2020 time horizon, households and employment tend to locate primarily in existing, built-up areas northeast, east, and immediately south of the central business district (CBD). In general, household and employment location tends to follow land development; however, density increases in some zones. From 1990 to 2020, floorspace in the base case scenario increased by 1000 million sq. ft. The land use results for the other scenarios are discussed in comparison to the future base case scenario.

In the highway investment scenarios (HOV and beltway), industry locates further away from the households that it serves and employs. Employment location is more intense in the existing, built-up areas northeast, east, and immediately south of the CBD, and in the CBD. The distant eastern zones that include the cities of Auburn and Folsom lose commercial employment and become more like “bedroom communities” compared to the base case scenario. As a result of increased roadway capacity, retail activity can shift from local commercial to more remote zones where “big-box” retailing is likely to occur. Rancho Cordova becomes increasingly important as a commercial node east of the City of Sacramento and west of Folsom. These activity patterns produce an increase in floorspace consumption, 4.3 million sq. ft. for the HOV scenario and 3.65 million sq. ft. for the beltway scenario. Table 4 presents the percentage change in household and employment floorspace (square feet) for the scenarios from the base case and the total change in acres of floorspace for the scenarios from the base case.

Table 4. Percentage change (from 2020) in household and employment floospace by superzone for the 2020 MEPLAN scenarios.

HOUSEHOLD SQ. FT.	HOV	BELTWAY	**LRT**	PRICING	PRICING +LRT	URBAN RESERVE + INFILL +LRT	PRICING +URBAN RESERVE +INFILL +LRT	UGB +LRT	PRICING +UGB +LRT
Sacramento CBD (13)	-0.5%	-0.6%	0.0%	1.1%	1.3%	0.2%	0.9%	2.8%	3.7%
Citrus Hgts/Roseville (70,71,4)	-0.3%	-0.5%	0.2%	0.2%	0.3%	0.4%	0.1%	3.8%	3.4%
Rancho Cordova/Folsom (6,12)	-1.4%	-1.2%	0.1%	-0.3%	-0.1%	0.5%	-0.1%	4.8%	4.9%

Inner Suburbs (1-3, 7-11, 14, 16, 25)	-0.3%	-0.4%	0.0%	0.3%	0.4%	0.2%	0.1%	1.4%	1.4%
Outer Ring (Remainder)	1.4%	1.5%	0.1%	-0.6%	-0.5%	-0.5%	-0.4%	-14.9%	-15.1%
Total	0.4%	0.4%	0.1%	-0.2%	-0.1%	-0.1%	-0.1%	-5.5%	-5.6%
EMPLOYMENT									
Sacramento CBD (13)	1.4%	1.2%	0.6%	0.6%	2.7%	0.7%	2.4%	3.1%	4.6%
Citrus Hgts/Roseville (70,71,4)	0.1%	0.0%	0.1%	0.1%	0.4%	0.1%	0.3%	2.1%	2.1%
Rancho Cordova/Folsom (6,12)	3.1%	1.9%	-0.5%	-0.5%	2.5%	-0.6%	2.2%	2.6%	5.8%
Inner Suburbs (1-3, 7-11, 14, 16, 25)	0.7%	0.5%	0.2%	0.2%	1.3%	0.3%	1.1%	0.9%	1.8%
Outer Ring (Remainder)	-2.7%	-2.3%	0.5%	0.5%	-2.2%	0.3%	-1.7%	-8.0%	-8.6%
Total	-0.4%	-0.5%	0.2%	0.2%	0.0%	0.2%	0.2%	-2.1%	-1.6%
Total change in acres of floorspace (millions of sq. ft.)	4.30	3.65	2.92	-1.12	-1.38	-0.71	-1.88	-109.87	-108.07

In the LRT scenario, household and employment location tends to follow the light rail lines. The improved mobility resulting from the transit investment allows some increased separation between household and employment location and an increase in floorspace consumption (2.92 million sq. ft.), compared to the base case scenario. The change in household floorspace consumption is minimal, but there is a small increase in employment floorspace consumption in the CBD (0.6%) and in the outer ring (0.5%).

In the pricing only scenario, region-wide parking pricing and a VMT tax increase the location of activities and the consumption of floorspace in the CBD, for both households and employment (1.1% and 0.6%, respectively). There are reductions in floorspace consumption in the outer ring for households (0.6%) and in the Rancho Cordova-Folsom zones for both households and employment (0.3% and 0.5%, respectively). Floorspace consumption is reduced by 1.12 million sq. ft. in this scenario compared to the base case scenario.

The addition of pricing policies to the LRT network reverses the decentralization of activity location in the LRT only scenario. There are relatively large increases in activity location and floorspace consumption in the CBD for both households and employment (1.3 and 2.7%, respectively) and a reduction in the outer ring for both employment and households (0.5 and 2.2%, respectively). Floorspace consumption is reduced by 1.38 million sq. ft. in this scenario compared to the base case.

In the urban reserve and infill scenarios, the 20 percent subsidy for infill development results in modest gains in the more central areas of the region

(0.2% for household floorspace and 0.7% for employment floorspace). The urban reserve policies resulted in only a 0.5 percent reduction in household floorspace consumption in the outer ring. In this scenario, floorspace consumption was reduced by a total of 0.71 million sq. ft.

When pricing policies are added to the urban reserve and infill policies, development is significantly intensified in the CBD (0.9% and 2.4%) and increased somewhat in the inner areas of the region. In this scenario there is a relatively large increase in the reduction of floorspace consumption in the outer ring for employment compared to the base case, but compared to the pricing and LRT scenario the reduction is dampened. In this scenario, floorspace consumption is reduced by 1.88 million sq. ft.

The UGB policy has a dramatic affect on activity location and development. For the outer rings, there is an almost 15 percent reduction in household floorspace consumption compared to the base case scenario and an 8 percent reduction in employment floorspace consumption. There are relatively large increases in employment and household development along the light rail lines, particularly in the CBD (2.8 and 3.1%, respectively), Citrus Heights-Roseville (3.8 and 2.1%, respectively), and Rancho Cordova-Folsom areas (4.8 and 2.6%, respectively). Floorspace consumption is reduced by 109.87 million of sq. ft. in this scenario, compared to the base case scenario.

When the pricing policies are added to the UGB policy, changes in activity location and development are even more dramatic. There is a larger increase in activities and floorspace consumption in the CBD (3.7 and 4.6%), Rancho Cordova-Folsom (4.9 and 5.8%), and inner suburbs (1.4 and 0.9%). There is a greater reduction in floorspace consumption in the outer ring (15.1 and 8.6%). It appears the pricing policies may reduce congestion somewhat, compared to the UGB scenario, and allow development to spread out more to the inner suburbs and the Rancho Cordova-Folsom areas. The reduction in total floorspace consumption is dampened somewhat, compared to the UGB only scenario (108.07 million sq. ft.).

TRAVEL

Mode Share

The mode share results are presented in Table 5. In both the HOV and Beltway scenarios, there is an increase in the HOV mode share, compared to the base case scenario (5.7% and 7.8%, respectively). Faster travel times resulting from the HOV lanes in the HOV and Beltway scenarios make carpooling more attractive than most of the other available modes. In the HOV scenario, there is a reduction in the drive alone, transit, walk, and bike mode shares. In the Beltway scenario, there is a reduction in the drive alone, walk, and bike mode shares, but also a slight increase in the transit mode share. This is due to the faster travel times by commuter buses that are allowed to use HOV lanes and differences between the land uses in the scenarios.

Table 5. Daily mode share projections for the MEPLAN scenarios.

SCENARIOS	DRIVE ALONE	SHARE RIDE	TRANSIT	WALK & BIKE
Base	45.1	43.7	1.9	9.3
HOV	43.2 (-4.2%)[1]	46.2 (5.7%)	1.8 (-5.4%)	8.8 (-5.3%)
Beltway	43.2 (-4.2%)	46.3 (5.8%)	1.9 (1.1%)	8.6 (-7.1%)
LRT	44.0 (-2.5%)	42.4 (-3.0%)	5.4 (191.4%)	8.2 (-11.9%)
Pricing	29.2 (-34.6	51.7 (18.3)	3.8 (102.7%)	15.3 (64.4%)
Pricing + LRT	29.5 (-34.6)	48.4 (10.6%)	9.6 (415.1%)	12.6 (35.0%)
Urban Reserve + Infill + LRT	44.1 (-2.3%)	42.4 (-3.2%)	5.3 (186.0%)	8.3 (-11.0%)
Urban Reserve + Infill + LRT + Pricing	29.4 (-34.9%)	48.5 (10.8%)	9.7 (423.1%)	12.4 (33.8%)
UGB + LRT	44.2 (-2.0%)	41.1 (-6.1%)	5.6 (201.6%)	9.1 (-1.7%)
UGB + LRT + Pricing	29.2 (-35.3%)	47.7 (9.0%)	10.1 (442.5%)	13.0 (40.1%)

1 Percentage change from the base scenario.

The light rail and advanced transit investments result in faster transit travel times in the LRT scenario and produce a relatively large gain in the transit mode share (191.4%) and losses in the drive alone (2.5%), shared ride (3.0%), and walk and bike (-11.9%) mode shares.

The region-wide parking charge and the 5 cent VMT tax result in almost a 35 percent reduction in the drive alone mode share. There are large increases in the modes for which these charges do not apply (i.e., transit, walk, and bike modes) or are lower (i.e., shared ride). When the light rail network is added to the pricing policies, there is a larger increase in the transit mode share (451.1%), a reduction in the shared ride, walk, and bike mode shares, and little change in the drive alone mode. Faster travel times by transit attract travelers away from the shared ride, walk, and bike modes.

In the urban reserve, infill, and LRT scenario, transit mode share is increased compared to the base case scenario (186.0%), but it drops just slightly below the results for the LRT only scenario. Again, the drive alone, shared ride, walk, and bike mode shares are all reduced in this scenario, compared to the base cases. Faster travel times by transit attract travelers away from the auto and non-motorized modes to transit. When pricing policies are added to this scenario, again, we see large reductions in the drive alone mode share and large increases in the shared ride, transit, walk, and bike mode shares.

In the UGB and LRT scenario, there is a large increase in transit ridership (201.6%), which is higher than in the LRT only scenario. There are reductions in the drive alone, shared ride, walk, and bike mode shares. Compared to the LRT only scenario, the reduction is doubled for the shared ride mode share, and the reduction is lower for the drive alone and walk and bike mode shares. It appears that the UGB has successfully increased transit accessibility. It is difficult to represent the affect that UGBs, which would most likely be combined with urban design policies, could have on the walk and bike mode share. This is because the Sacramento MEPLAN model uses large zones and does not explicitly include variables that represent the “walkability and bikeability” of neighborhoods.

When pricing policies are added to the UGB and LRT scenarios, the reduction in the drive alone mode share is greatly reduced (35.3%) and transit ridership is greatly increased (442.5%), compared to both the base case and the UGB and LRT policies. However, shared ride, walk, and bike mode shares are increased in this scenario. Auto travel times are faster in this scenario than in the UGB and LRT scenario because of the auto pricing policies. In addition, the shared ride mode offers a break on auto pricing policies, and thus this mode becomes more attractive. The walk and bike modes are free in this scenario and there is a greater concentration of activities in the CBD.

Vehicle Travel

In the HOV and Beltway scenarios, the HOV lanes provide faster travel times by the carpool mode to produce larger shared ride mode shares and smaller drive alone mode shares and thus a decrease in vehicle trips. Despite these mode shifts, significantly reduced peak auto travel times (-9.2 and -12.8%, respectively) resulting from the increased highway capacity produce longer trip lengths and an increase in VMT (4.7 and 8.9%, respectively). See Table 6.

Table 6. Vehicle travel results for the MEPLAN scenarios.

	DAILY TRIPS (THOUSANDS)	DAILY VMT (MILLIONS)	PEAK MEAN TRAVEL TIME (MINUTES)	PEAK TRAVEL SPEED (MPH)
BASE	540.8	4.49	29	21
HOV	535.5 (-1.0%)	4.7 (4.7%)	26 (-9.2%)	25 (20.6%)
BELTWAY	535.5 (-1.0%)	4.89 (8.9%)	25 (-12.8%)	27 (28.8%)
LRT	527.2 (-2.5%)	4.27 (-4.9%)	29 (1.6%)	20 (-1.8%)
PRICING	433.0 (-19.9%)	3.50 (-22.1%)	23 (-18.8%)	26 (24.1%)
PRICING + LRT	424.2 (-21.6%)	3.28 (-26.9%)	24 (-17.6%)	26 (24.1%)
URBAN RESERVE + INFILL + LRT	527.7 (-2.4%)	4.23 (-5.8%)	28 (-0.7%)	21 (-0.1%)
URBAN RESERVE + INFILL + LRT + PRICING	423.6 (-21.7)	2.09 (-53.3%)	25 (-14.5%)	25 (20.8%)
UGB + LRT	519.0 (-4.0%)	4.06 (-9.6%)	26 (-9.6%)	22 (7.4%)
UGB + LRT + PRICING	414.6 (-23.3%)	2.03 (-54.9%)	22 (-24.9%)	27 (33.0%)

1 Percentage change from the base scenario.

In the light rail scenario, faster travel times by transit shift trips from the auto modes to transit, and thus vehicle trips and VMT are reduced. There is a reduction in peak travel speeds and an increase in peak travel times in this scenario. Some congestion on roadways is necessary for transit to compete effectively with the autos for travelers.

The costs imposed on the auto modes in the pricing scenario produced large reductions in vehicle trips (20%) and VMT (22%), significantly reduced peak travel times (19%), and increased peak travel speeds (28%). When light rail is added to the pricing policies, the reduction in vehicle trips and VMT is increased, (26.9%) but there is a smaller reduction in peak travel time (17.6%) and a smaller increase in peak travel speed (24.1%). These results are consistent with the results of the light rail only scenario.

The pricing only and the pricing and light rail scenarios produce reductions in peak travel time that are greater than the HOV lane and the Beltway scenarios and increases in peak travel speed that are greater than the HOV lane scenario and almost as great as the Beltway scenario.

The addition of the urban reserve and infill policies to the LRT policy produces only slightly greater reductions in VMT and slightly greater reductions in congestion. The addition of the pricing policy improves these results.

In the UGB and LRT scenario, there is an increase in the reduction of vehicle trips (4%), VMT (10%), and travel time (33%), compared to the LRT only scenario. The reduction in peak travel time is greater than that obtained for the HOV lane scenario. When pricing policies are added to the scenario, the reduction in vehicle trips and VMT is dramatically increased. These reductions are larger than the results for the pricing and LRT scenario. There are also large reductions in peak travel time and large increases in peak travel speed, which are both larger than the results for the HOV and beltway scenarios.

EMISSIONS

The daily emissions results are presented in Table 7. The scenarios tend to rank with VMT results. The HOV and Beltway scenarios increase vehicle emissions. The beltway scenario increase in emissions is relatively large (8.1% for NOx). The LRT only scenario results in small emission increases because the emissions from the new buses included in the scenario are included in the analysis. The Urban Reserve, Infill, and LRT scenario provides relatively modest reductions in emission. The UGB and LRT scenario provides somewhat greater reductions (3.8% for NOx). The pricing policies provide dramatic reductions in emissions (20% to 24% for NOx).

Table 7. Daily emissions results for the MEPLAN scenarios.

	TOG (TON)	CO (TON)	NOX (TON)	PM (TON)
Base	14.2	124.4	55.1	84.6
HOV	14.5 (2.1%)[1]	126.1 (1.4%)	55.6 (0.9%)	84.8 (0.3%)
Beltway	15.0 (6.2%)	134.9 (8.4%)	59.5 (8.1%)	87.7 (3.7%)
LRT	14.4 (2.0%)	122.9 (1.0%)	54.6 (0.6%)	83.3 (1.0%)
Pricing	10.3 (-27.0%)	95.9 (-22.9%)	44.3 (-19.6%)	60.4 (-28.5%)
Pricing+LRT	10.2 (-28.1%)	94.0 (-24.4%)	43.4 (-21.1%)	58.8 (-30.5%)
Urban Reserve+Infill+LRT	14.1 (-0.1%)	123.8 (-0.4%)	54.9 (-0.3%)	83.3 (-1.6%)
Urban Reserve+Infill+LRT+pricing	10.4 (-26.7%)	103.0 (-17.2%)	43.9 (-20.4%)	60.6 (-28.4%)
UGB+LRT	13.8 (-2.4%)	119.9 (-3.6%)	53.0 (-3.8%)	79.2 (-6.4%)
UGB+LRT+pricing	9.8 (-30.9%)	97.7 (-21.5%)	41.6 (-24.4%)	56.4 (-33.4%)

[1] Percentage change from the base scenario.

TOTAL BENEFIT AND EQUITY RESULTS

Table 8. Results of the benefit measure (by income class and total) for the MEPLAN scenarios

	Low Income	Middle Income	High Income	Total
HOV	$18,879.45	$106,279.27	$108,824.06	$233,982.78
Beltway	$23,049.16	$131,842.02	$147,374.01	$302,265.19
LRT	$6,355.57	$20,670.95	$19,951.45	$46,977.97
Pricing	-$9,794.04	$45,998.71	$70,253.02	$106,457.68
Pricing+LRT	$7,492.15	$53,927.22	$57,407.59	$118,826.96
Urban Reserve+Infill+LRT	$4,144.17	$12,028.19	$13,746.55	$29,918.92
Urban Reserve+Infill+LRT+pricing	$6,194.64	$44,517.03	$40,242.98	$90,954.66
UGB+LRT	$17,024.72	$78,456.51	$64,639.64	$160,120.87
UGB+LRT+pricing	$13,932.36	$87,068.19	$92,669.60	$193,670.14

Notes: the benefit measure captures change in travel cost and time for all modes from the base case scenario for the work trip purpose for the a.m. peak hour only; figures are in 1990 dollars; capital and O&M costs are not included in the benefit measure; none of the auto pricing charges are returned to travelers the pricing scenarios.

The total benefit and equity results are presented in Table 8. The results in Table 8 indicate that, for most of the scenarios, the higher income classes benefit from the new transportation projects, pricing policies, and land use policies more than the lower income groups. The higher income groups have a higher value of time than the lower income groups. As a result, the travel time saving to the higher income classes from the projects and policies in the scenarios are weighted more heavily. Alternative values of time and marginal utility of income assumptions can be used to address the income bias in benefit analysis. It is also possible that the facility location benefits the higher income classes more than the lower income classes. The examination of equity measures (like the one in this study) can help highlight potential disparities in capital investment facility location.

The only policy scenario in which the lowest income group loses is in the pricing only scenario. When the pricing policies are combined with the LRT investments (in the pricing and LRT scenario), then these losses are offset. It is likely that the LRT in the pricing and LRT scenario serves as a low cost alternative to the more expensive auto modes.

With respect to total regional economic benefits, the HOV and beltway scenarios produce the greatest benefits and the LRT only scenario produce benefits that are much lower. The highway networks in these scenarios, however, represent a larger investment and serve a greater number of travelers than the LRT network. In addition, the capital and operation and maintenance costs are not included in the benefit analysis; (however, past research by us in the region has indicated that inclusion of these costs will not change the rank ordering of scenarios). Further research needs to be conducted with highway and transit networks that represent similar levels of investment. The UGB scenarios combined with LRT only and the pricing policies produced the next greatest level of benefits. As discussed in the travel results, the UGB policies and the pricing policies produced substantial reductions in peak travel times. The pricing only and the pricing and LRT scenarios produced the next highest benefits. Again, both of these policies produced significant reductions in peak period travel times. The benefit results for the urban reserve and infill subsidy policies (i.e., with LRT and/or pricing policies) are comparatively low.

In general, the benefit results are consistent with the peak vehicle travel time and speed results in Table 6 (vehicle travel results). Transit serves a relatively small share of the region's travelers, and thus changes in transit service do not significantly affect total benefits in the region. Again, the results of this study suggest the need for further research of a more aggressive expansion of transit service in the region. The benefit measure should also be expanded to include capital and operation and maintenance costs.

CONCLUSIONS

A number of conclusions can be made based on the results of this case study.

(1) Transportation investment in both highway and light rail may allow for greater decentralization of regional development. Land use and pricing policies may be used to “tame” the decentralizing effects of transportation investments. The HOV and beltway scenarios allowed for greater separation of household and employment development and increased regional floorspace consumption. The LRT scenario also allowed for decentralization of activities along light rail lines and increased regional floorspace consumption. When pricing and land use policies were added to the LRT network, this decentralizing trend was dramatically reversed.

(2) New highway capacity projects, even if they include HOV lanes, may increase VMT and emissions. The HOV and beltway projects in the scenarios evaluated in this study increased household development in the outer areas of the region and increased total floorspace consumption region-wide by approximately 3 to 4 million sq. ft. These land use patterns contributed to relatively large increases in VMT (4.7 and 8.9%, respectively) and emissions (0.9 and 8.1%, respectively for NOx), despite reductions in the drive alone mode share and increases in the shared ride mode.

(3) Transit investment with supportive land use policies and/or pricing policies may be very effective in reducing VMT and emissions. For example, we found a 4 to 24 percent reduction in NOx emissions for the pricing, urban growth boundary, urban reserve, and infill policies in this study.

(4) Transit investment with supportive land use and/or pricing policies may provide congestion reduction that is as great, if not greater, than highway investment policies. The HOV lane and the beltway scenario produced a 9 and 13 percent reduction in peak travel time, and the transit with supportive land use and/or pricing policies produced a reduction in peak period travel time of 10 to 25 percent.

(5) The highway investment policies may, however, provide the greatest level of benefit (i.e., changes in travel time and cost from the base case) compared to transit with and without supportive land use, and/or pricing scenarios. This conclusion is tentative and requires further research for a number of reasons. First, the

alternative transit investment was smaller than the highway investment scenarios and served far fewer travelers. More research is needed to compare the highway investment scenarios with a comparable transit scenario. The UGB, LRT, and/or pricing scenarios did provide large benefits. Second, the auto pricing charges were not returned to travelers in the benefit results. It is likely that a portion of the auto pricing charges would be refunded to travelers in some way. Further research should be conducted to determine whether pricing policies could result in benefits that are larger than those obtained for the highway scenarios. As discussed in (4) above, the travel time benefits of the pricing and UGB policies did compare more favorably, in some instances, to the highway scenarios.

(6) Equity measures are useful to identify possible disparities in the benefits that may result from the location of transportation investments and policies that may result in losses to certain groups. With this knowledge, it may be possible to redesign policies to redress losses to certain groups. For example, in this study, the results suggested that auto pricing policies alone could result in losses to the lowest income class; however, these losses were offset when the policies were combined with transit investment.

In sum, if the scenarios in this report are evaluated against four criteria, (1) congestion reduction, (2) emissions reduction, (3) total regional benefits and benefits by income class, and (4) protection of environmentally sensitive lands, then the LRT with the UGB and/or the pricing scenarios are the clear winners. The conclusions of this report strongly suggest that a fair evaluation of proposed new highway projects should use state-of-the-practice methods that represent induced travel effects and should analyze alternatives that include transit investment accompanied by supportive land use and auto pricing policies.

REFERENCES

Abraham, J. E. *Parameter Estimation in Urban Models: Theory and Application to a Land Use Transport Interaction Model of the Sacramento, California Region*. Calgary, Canada: Ph.D. Dissertation, Department of Civil Engineering, University of Calgary, 2000.

Cambridge Systematics Inc. et al. *Analysis of Alternatives: Making the Land Use Transportation Air Quality Connections*. Portland, Oregon. May, 1996.

DKS Associates. *Model Development and User Reference Report.* Sacramento

Area Council of Governments, Sacramento, CA, October. (1994)

Hunt J. D., and M. H. Echenique. *Experiences in the application of the MEPLAN framework for land use and transportation interaction modeling.* Daytona Beach, Florida: Proceedings of the 4th National Conference on the Application of Transportation Planning Methods, 723-754, May 1993.

Hunt, J. D. "Calibrating the Naples land use and transport model." *Environment and Planning* 21B: 569-590, 1994.

Johnston, R.A., C.J. Rodier, J.E. Abraham, and G.J. Tonkin. *Applying an Integrated Model to the Evaluation of Travel Demand Management Policies in the Sacramento Region.* Norman Y. Mineta International Institute for Surface Transportation Policy Studies. June, 2000.

Leontif, W. *The Structure of the American Econom*y 1919-1939, New York, NY: Oxford University Press, 1941.

McFadden, D. "Conditional logit analysis of qualitative choice behavior." *Frontiers in Econometrics*, Editor: Zaraembka P. New York, NY: Academic Press, 105-142, 1974.

Meyer, M. D., and E. J. Miller. *Urban Transportation Planning: A Decision-Oriented Approach*. New York, NY: McGraw-Hill, 1984.

Pyatt, G., and E. Thorbeck. *Planning Techniques for a Better Future. International Labour Office*, Geneva, Switzerland, 1976.

Williams, H. C. W. L. "On the formation of travel demand models and economic evaluation measures of user benefit." *Environment and Planning* 9A(3):285-344, 1977.

GLOSSARY OF ABBREVIATIONS AND ACRONYMS

CAAA	Clean Air Act Amendments
CBD	Central Business District
DTIM2	The California Department of Transportation's Direct Travel Impact Model 2
ECOS	An environmental umbrella group
EPA	Environmental Protection Agency
FAF	Calculated by MEPLAN's interface module FREDA
FREDA	MEPLAN's interface module
GIS	Geographic Information Systems
HOV	High Occupancy Vehicle
LUSB	Incremental Land Use Model
MEPLAN	Model to evaluate transit and supportive land use and pricing policies
NEPA	National Environmental Policy Act
SACMET	Regional Travel Demand Model
SACOG	The Sacramento Area Council of Governments
SAC-TE	An umbrella group of neighborhood and social equity groups
SAM	Social Accounting Matrix
TOD	Transit Oriented Development
TAD	Calculated by MEPLAN's transport assignment and mode split module, TASA
TASA	Transportation assignment and mode split module
TASB	Transportation assignment and mode split module
VMT	Vehicle Miles Traveled

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Robert A. Johnston is Professor of Environmental Science and Policy and a Faculty Researcher at the Institute of Transportation Studies at the University of California at Davis. Current consulting involves the evaluation of regional travel demand models for public and private clients, reviews of environmental assessments of large projects, and the development of methods for projecting environmental carrying capacity at the national level.

Johnston's current research projects include the evaluation of transportation policies using advanced regional travel demand models. The mode choice models have been modified to permit the projection of traveler net benefits (surplus) for each scenario, broken down by household income class.

He also is performing research using an integrated urban model of the Sacramento region. This model simulates land markets and travel behavior, which permits the projection of the interactions between land uses and travel demand. This model allows the assessment of locator surplus, by household income class.

Related projects are the linking of the integrated urban model to a GIS-based model, which produced detailed land use maps. These maps are then used with other data layers to perform environmental impact assessments. Another project is a comparison of three integrated urban models on the same datasets for the Sacramento region.

Recently completed work includes financial and economic evaluations of regional transportation alternatives, including ITS roadway and transit scenarios. Current work includes performing long-range (50-year) analyses of sustainable development scenarios for the Sacramento region using an urban model and GIS, in conjunction with business and citizens groups. He is also adapting the GIS to make it interactive and run on a PC, for single-county land development scenario testing.

Professor Johnston sits on state and regional advisory committees for transportation and air quality planning agencies and has been a member of a local transportation commission. He reviews articles and grant proposals for several organizations and has published over 60 refereed articles and book chapters. He has given invited talks at many conferences and universities and has been a faculty member-in-residence at the University of Iowa. He is a member of the TRB Transportation and Land Development Committee and heads the Sustainable Communities Consortium at UC Davis.

CAROLINE J. RODIER

Caroline Rodier has a Ph.D. in Ecology, focusing on environmental policy analysis and transportation planning. As a graduate student and, more recently, as a post-graduate researcher and independent consultant, she has designed, managed, researched, and helped procure funding for a number of public research projects. The research for these projects includes the use of integrated land use and transportation, regional travel demand, and emissions models to evaluate the travel, economic, equity, and air quality effects of a wide range of transportation and land use policies. Her dissertation addresses key issues of uncertainty in travel and emissions modeling, in particular, population projections and induced travel. She has earned a variety of awards including the University of California Outstanding Transportation Student of the Year, the Federal Highway Administration's Dwight David Eisenhower Transportation Fellowship, and the Environmental Protection Agency's Science to Achieve Results Fellowship. She has authored more than ten journal articles and twenty reports and proceedings articles.

JOHN E. ABRAHAM

John has expertise in developing and calibrating models to provide computer simulations that are both accurate and practical for analyzing policy and scenarios. His development and use of models has focused on understanding and measuring the relationship between the transportation system and the larger community, and modeling these relationships in land use transport interaction models. He is an expert on survey techniques for understanding preferences, measuring tradeoff rates and predicting behavior. Surveying projects include surveys to predict mode choice in Phoenix, Ohio, Calgary, Edmonton and Kathmandu (Nepal), and surveys to understand broad citizen preferences in Calgary and Edmonton. Modeling projects include land use and transportation models of the Sacramento region and the State of Oregon, a model of the demand for passenger traffic on the Channel Tunnel Rail Link, a model of cyclist's preferences of Edmonton, a mode choice model for Kathmandu, Nepal, and a review of the land use model of Auckland, New Zealand. As a volunteer, John has worked with stakeholder groups and community associations, and is chair of the Calgary Alternative Transportation Co-operative. John is also president of T.J. Modelling Ltd.

JOHN DOUGLAS HUNT

Doug is an internationally recognized and widely published expert in land use and transport interaction modeling. He has about 15 years of experience in transportation demand modeling and land use transport interaction modeling in Europe, the United States, and Canada. He has assisted in the successful development of multimodal transportation models or land use and transportation interaction models for various cities, including: London, Edinburgh, Dortmund, Naples, Dublin, San Diego, Sacramento, Phoenix, Edmonton and Calgary. He was a special modeling advisor to Union Railways, the British Rail subsidiary developing the Channel Tunnel Rail Link, for 4 years. He has also worked on regional transportation and land use model for Oregon, Sweden, Southeast England and Central Chile. His special expertise is in the design and calibration of these models, developing them so that they can be used to examine policy alternatives involving such things as infrastructure development, alterations in land use regulations, changes in transportation conditions (including operations, tariffs and user costs) and new economic and fiscal arrangements. His experience in both private consulting and university teaching and research make him a powerful communicator with a broad understanding of both the technical issues and the practical constraints involved in real-world modeling work. Doug is a professor of Transportation Engineering at the University of Calgary and president of Hunt Analytics Incorporated.