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Publication Date
1993

CALIFORNIA PATH PROGRAM
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

A Continuing Systems-Level Evaluation of Automated Urban Freeways: Year Three

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UCB-ITS-PRR-93-15

This work was performed as part of the California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation; and the United States Department of Transportation, Federal Highway Administration.

OCTOBER 1993

ISSN 1055-1425

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EXECUTIVE SUMMARY

This is a systems analysis using an existing, regional travel demand model. The Sacramento regional model set was used and an alternatives analysis was conducted. The model was not re-estimated or recalibrated for this study. The model was deemed sufficient since we are conducting a comparative analysis of policies and modeling methods.

Many MPOs and local planning agencies use a typical UTPS 4-step modeling process. Our aim here has been to improve this modeling process so that it is more sensitive to travel impedances. Historically in the modeling process to generate an origin-destination matrix, a set of travel impedances was calculated at the trip distribution step, usually based on posted or free flow speeds on the highway network. This O-D matrix was then used in the remaining 4-step process to estimate the travel parameters which are then used in systems-level analysis, policy analysis etc. A better method would be to develop an origin-destination matrix based on a congested assigned travel impedances. In our case this has been achieved by feeding travel impedances from the assignment step back to the trip distribution level. This is done iteratively 6 times and the results averaged.

Feeding travel impedances back to the trip distribution step results in decreased VMT, VHT, VHD, etc. There is an 8 to 10% decrease in VMT and approximately a 40% decrease in VHD across a set of 20-year alternatives. This shows the necessity of feedback in travel demand modeling to prevent overprojection of travel.

A thorough alternatives analysis shows that freeway automation reduces VHD but increases VMT compared to conventional alternatives. TDM alternatives provide us with the lowest VMT but higher VHD than automation. Pricing has a significant effect on all alternatives by reducing both VMT and VHD. Our results are compatible with those in earlier studies.

PURPOSE AND OBJECTIVES

This study was undertaken for Caltrans in order to demonstrate the travel and emissions impacts of urban freeway automation scenarios and to compare these to travel demand reduction scenarios, such as travel pricing and land use intensification. We operate the Sacramento regional model set in our lab, as all of the component models are implemented on PCs. The Sacramento regional model has been used for its reasonable complexity that includes most types of modes especially **HOVs,** well defined freeway and arterial systems and its treatment of all the components of a UTPS model using contemporary methodologies.

We operate the model set in two ways. The first protocol is with feedback of congested speeds just to the mode choice step, the conventional method and the one required by the federal transit funding agency until recently. Second, we operate the model set with full feedback of congested travel times until we can estimate the equilibrium output values for VMT and **VHT.** This is the theoretically proper method and is valid if the model runs are converging (they do) and if the F-factors in the trip distribution model are for the peak (congested) period (they are).

In our Results section, we discuss the substantive results, comparing the alternative scenarios, and also discuss our methodological findings, comparing the results from the two protocols for operating the model set. Our methodological findings present new ideas of interest to modelers, regarding the differential effects of congestion on the various alternatives.

This report will be reviewed by our advisory committee, before we continue the project with the 1992-93 funding.

LITERATURE REVIEW

A. Urban Freewav Automation

We identified the demand-inducing aspects of automation as a possible problem in an early overview of the policy issues involved with the automation of urban freeways (Johnston, et al., 1990). No assessments of the effects of freeway automation on travel demand and on emissions have been done with a full set of models iterated on congested (assigned) speeds. We wished to carefully evaluate the effects of various scenarios on vehicle-trips, VMT, speeds, and emissions, as well as on VHD and lane-miles of congestion.

In another recent paper, we performed a break-even evaluation of the time savings necessary to recoup the costs of automating various types of vehicles (Johnston and Page, **JTE,** in press). Using high and low values for capital and operating costs, we found that automation clearly was financially worthwhile for the owners of heavy-duty vehicles, but would likely not pay for light-duty vehicles. This presents a major problem, since the Caltrans program until recently was oriented toward the light-duty vehicle. Underwood (1990) found that cost to the consumer was the first-ranked issue for a panel of experts. As a result of our paper and Underwood's findings, we have identified automated HOV lanes as one possible system that will be cost-effective for light-duty vehicle owners. We wanted to evaluate add-a-lane HOV and take-a-lane HOV in our research.

SCAG (1992), in cooperation with PATH, performed a study of automated freeways in Southern California for the year 2025. The identification of market penetration scenarios was useful; however, the models were run on one set of trip tables, to save money (the SCAG UTP models cost about $10,000 for one run, and full iteration takes several runs). The automation scenarios were at 55 mph (the models capped speeds at 55 mph, and so higher speeds could not be simulated). Capacity was set at 6,000 vehicles per hour per lane. Congestion was projected to decrease on freeways and arterials and increase on ramps. There was a 6% reduction in ROG, due to less VMT at low speeds. The modeling, however, did not account for the effect of increased speeds on trip lengths, which go up proportionately. Also, the model was run for the a.m. peak only, so the effects of automation on off-peak travel were not projected. With our models on PCs, we wished to test the full effects of automation on peak and nonpeak travel.

Whereas there is very little literature evaluating the systemwide effects of automating urban freeways, there is research that looks at the effects of adding freeway capacity in general. Since most automation scenarios are at 55-70 mph, these studies should be directly applicable. There is general agreement that reductions in travel time will have a series of effects on:

1. Route choice. Added freeway capacity will pull autos off of arterials and onto freeways.
2. Mode choice will move from transit and HOV to SOV.
3. Departure times will move from offpeak and shoulder to peak.
4. Trip distribution will expand, with longer trips resulting from the faster travel times.
5. Trip generation should also be affected, with less trip chaining and more trips per day.
6. Auto ownership will rise, if highway accessibility is significantly improved relative to

transit accessibility. Higher levels of auto ownership bring about higher levels of motorized trip generation.

7. Locations of new residential and employment land uses will move outward, because of the longer trip lengths. (This list of travel behaviors can be found in texts and in Harvey and Deakin, 1991 and Stopher, 1990).

Route choice and mode choice are handled fairly well in most models, that is they are determined by travel times to the various zones in the region. Departure time (peak spreading) models do not exist, except in a few regions, and so the effect of added capacity on increasing the peak-period share of trips is not represented; i.e., congestion is underprojected.

Trip distribution models generally can represent the effect of higher speeds on increasing trip lengths. However, most MPOs do not iterate the model steps on congested travel times and so this effect is suppressed. This improper method is used to save computer time, but seriously biases results by underprojecting VMT. The iteration of congested travel times to the trip distribution step is recommended by all modeling texts, such as Ben-Akiva and Lerman (1985). Kanafani (1983) and Mannheim (1979) state that the UTP models are not operated in this way and so are not valid. Conference papers also argue for the equilibration of model steps on congested travel times (Ruiter and Dial, 1979; Wilson, 1979).

Trip generation in most models is exogenous to the travel modeling and so is not affected by increased accessibility. Some models now use auto ownership to link accessibility to trip generation. Auto ownership models are explained in Ben-Akiva and Lerman (1985). Trip generation models should also directly account for accessibility, calculated discretely for each household in the travel survey. Auto ownership steps are used in only a few regions and so the effects of added capacity on trips is not simulated.

Very few regions operate land allocation models, so that the effects of changes in accessibility on land development can be projected. All of the large MPOs in California have such models or are developing them, because of the concern for accuracy in air quality conformity analyis. To the extent that major roadway improvements encourage low-density land use projects and the resultant higher auto ownership and VMT, the travel induced by road expansions will be underprojected.

Overall, most models underproject the VMT increases due to adding freeway capacity. This “oversight” was acceptable when most interest groups wanted more freeways and modeling was used primarily to determine the best routes to add or upgrade. Under the new clean air and transportation acts, however, there is very strong concern over the effects of improvements on travel and environmental groups are monitoring the modeling of the large MPOs. In some cases, these groups have run their own simulations and they intend to do so for the several largest regions. An example modeling exercise for Southern California is Cameron (1991). This nationwide oversight effort is discussed in the Clean Air/Transportation Report newsletter of the National Association of Regional Councils.

The effects on departure times, route choice, and mode choice are well-established, as are the effects on auto ownership. Kitamura (1991) reviewed the literature on these effects of added capacity for the FHWA and found that added freeway capacity could influence all of the behaviors discussed above, especially where there is severe congestion and, therefore, substantial latent demand. He emphasizes the general principle that increased capacity permits more growth on the urban edge with the resultant increases in travel. Kitamura apparently agrees with earlier researchers in the FHWA on this point (Zimmerman, et al., 1974).

Concerning the difficulty studies have in showing that increased roadway accessibility increases trip rates, Kitamura notes that accessibility measures have been based on zonal averages and exhibit little variation and explanatory power. Research is just now being done with discrete (GIS-based) accessibility measures for each household. The Portland, Oregon, model development, for example, found a useful relationship between land use density and mix and auto ownership, which in turn influences trip generation. Added highway capacity induces low-density residential land use, which increases auto ownership, which increases trip generation and reduces transit mode shares.

The increase in trip lengths is well-documented in several early studies (Voorhees, Barnes and Coleman, 1962; Bellomo, et al., 1970; Voorhees, et al., 1966; and Frye, 1963). Newman and Kenworthy (1989, 1988) have shown with data from districts within Perth and with aggregated data from 32 cities worldwide that faster roadway travel increases speeds and trip lengths, resulting in more fuel consumption. If a substantial portion of the travel is on freeways with speeds above 50 mph, one would expect that all pollutants would increase with the increased speeds. Hau (1987) found that road pricing would have much higher social benefits that adding SOV or HOV lanes. He used the Bay Area models in his study. An ITE (1988) report found that adding HOV lanes does not generally reduce volumes on adjacent freeway lanes, due to induced travel. The induction of travel by improved facilities also applies to transit improvements. The MTC (1979) found that the opening of BART had almost no effect on Bay Bridge traffic volumes. A DOE study (Suhrbier and Byrne, 1979) and a DOT report by Wagner and Gilbert (1978) both found that increasing road capacity would increase VMT.

Two recent studies (Downs, 1992; Small, Winston, and Evans, 1989) review a variety of policies intended to reduce congestion and conclude that these measures will induce more travel at peak periods. The measures included converted automated SOV lanes, new HOV lanes, and new SOV lanes.

B. Travel Demand Reduction Measures :

We also wanted to compare our automation scenarios to travel demand management policies. Many general overviews of transportation demand predict increased travel in developed countries in the future, due to higher incomes allowing increased levels of activity per capita. These researchers also predict a continuation of the shift to more energy-intensive modes. Even though each mode is becoming less energy-intensive, due to technological improvements, the increases in VMT and the switch to autos and airplanes for passengers and to trucks for freight is causing an increase in energy use in transportation per capita (Schipper and Meyers 1991). Vehicle growth exceeds population growth, especially in developing nations, and these nations will contribute much greater shares of pollutants and greenhouse gases in the future (Walsh, 1991).

In the U.S., the fact that travel costs have gone down, especially out-of-pocket costs, has increased travel, even in recent years when per worker incomes have fallen slightly. Shelter costs have risen as a proportion of income and are a larger share and so households have traded longer commutes for cheaper housing in the suburbs. In addition, basic employment is no longer dependent on rail facilities and so is also decentralizing (Wachs, 1981). All of these trends have caused concern and attention has focused on travel demand reduction measures. The

California Clean Air Act requires reductions in the rate of growth of VMT, increases in AVO during commute periods, and no net increase in mobile emission after 1997. The federal Clean Air Act requires annual reductions in nonattainment pollutants. Both acts require the adoption of all feasible TCMs, including TDMs.

A more detailed look at U.S. travel trends shows that from 1969 to 1990 trips per person and person-miles traveled rose much less rapidly than did autos per person and VMT per person. AVO dropped continuously and accounts for most of the increase in VMT per capita (FHWA, 1991). Some researchers think that these trends will level off as auto ownership saturates and as the growth rate of workers slows to near the population rate. Recent preliminary California data show that auto ownership rose substantially from 1978 to 1990 and driver trips per household rose 19%, reflecting the greater availability of cars. Trips per vehicle were unchanged and trip time-length was also unchanged. AVO fell (Caltrans, 1992).

An analysis of the 1990 Census for California shows that non-Anglo populations are growing rapidly, central cities are growing in population and density, outer suburbs are growing rapidly, inner older suburbs are losing population resulting in underutilized infrastructure, and jobs-housing imbalances are worsening in most metropolitan subareas due to fiscal zoning. Furthermore, the population over age 65 is growing very rapidly and in general urban growth is moving to the central valley where inversions make for bad air quality (California Governor's Office, 1991).

Land Use Policies

Considerable research has been done in California and elsewhere on TDMs. These may be generally categorized as land use measures and travel pricing measures. Let us first review the land use studies. There is great interest in growth management for reducing service costs, energy use, air pollution from vehicles, and fiscal inequities. The Governor's growth management council recently recommended the adoption of state growth statutes and the withholding of state funds to localities unless they comply with the policies. Several bills are in the hopper now outlining different methods of state growth management. The two main types of land use measures for TDM are jobs-housing balance and density increases near to transit facilities.

The general opinion is that jobs-housing balance (land use mix) will not reduce motorized trips and VMT much, because theoretically one expects workers to search for jobs within a 30-minute commute radius, not a shorter one, and therefore they end up with 25-minute commutes because the bulk of the jobs are in the outer area of their search pattern. A simulation study using models from several urban regions in developed countries found that jobs-housing balance reduced VMT by only a few percent, because of this phenomenon (Webster, Bly, and Paulley, 1988). SCAG simulated a regional jobs-housing balance policy and found that it could reduce VMT by 11% and VHD by 63% (SCAG, 1988a). The modeling was apparently done incorrectly, without full feedback of congested travel times to equilibration (SCAG, 1988b). Research by Giuliano and Small showed, however, that actual commute distances in Southern California were shorter for workers who worked in areas with poor jobs-housing balances (Giuliano, 1992). So the reduced VMT found by SCAG is probably on artifact of the model.

Analysis of Bay Area household survey data for selected suburban work zones showed that the availability of housing in a workplace zone slightly decreased commute travel distance and increased the share of commute trips by walk and bike. However, analysis of the same data for the entire region at the district level showed no relation between jobs-housing ratio and total daily VMT per capita (Harvey and Deakin, 1990). A simulation by MTC showed that increasing jobs-housing balance in areas near to transit stations decreased emissions per capita [corrected by us]. The scenario also increased densities in these areas and so the effects of the two policies cannot be separated (MTC, 1990, **ABAG** 1990).

A SANDAG empirical study found that jobs-housing balance at the zone of residence correlated with shorter commute trips (explained 3.3% of variation) (SANDAG, 1991). Our interpretation of all this conflicting evidence is that jobs-housing balance may help under future very congested conditions for roadways, if densities are sufficient to permit walking. One must remember, however, that if we increase rail transit availability (urban and commuter rail), workers can live farther away from their jobs (Wachs, 1989).

We note here that standard regional travel models peel off some trips to be intrazonal if there are trip attractions (employment) in the zone of the trip origin (households), and so may overrepresent the VMT reductions due to jobs-housing balance.

The evidence is much more positive and complete concerning density increase as a TDM. An international literature review found that there was some consensus that a system of many medium-sized cities with moderate densities or linear cities with moderately high densities would use less energy in transportation (Cope, Hills, and James, 1984). A recent review of urban data from 32 cities from around the world showed that higher densities greatly reduced VMT per capita (Newman and Kenworthy, 1989). Another international study used urban transportation and land use models from several urban areas to test TDM policies and found a fairly good consensus that higher residential densities reduced VMT per capita. Land use policies, however, were hardly effective unless accompanied by travel pricing polices and improved transit and walking/biking facilities. Reducing sprawl at the edge with urban growth boundaries also helps, in conjunction with pricing and transit improvements (Webster, Bly, and Paulley, 1988).

Several regional simulations of density policies have been done in the U.S. and they agree that such policies are effective, to some degree or another. A study of the Seattle region found that the concentration of growth into several centers would reduce VMT about 4% over 30 years, but there was no clear winner in terms of emissions, even when compared with a dispersed growth scenario. It appeared that the concentration of travel in the centers left the peripheral areas less congested and so people travelled farther in these areas (Watterson, 1991). This study is noteworthy because the travel models were run properly and land use models were also run, so that travel-land use interactions were captured. We note that a tighter urban growth boundary might have reduced VMT and emissions slightly more in the growth centers scenario, especially if road expansions were limited in these areas.

A simulation in Montgomery County, Maryland, showed that density policies, combined with pricing policies and the expansion of passenger rail, reduced single-occupant commute trips substantially (Replogle, 1990). The modeling was sophisticated, using land use variables in the equations for peaking factors and for mode choice. A review of several U.S. studies found that higher densities reduced auto travel and energy consumption about 20% over 20 years. The Washington D.C. regional study reviewed found that sprawled growth could use twice as much energy in travel as would dense centers with transit. Wedges and corridors, a less drastic scenario, reduced travel energy use by 16% (Keyes, 1976). A review of studies in several countries found that good transit service reduced auto ownership by 5-10% and that households with fewer autos had lower VMT (Colman, et al., 1991).

A study of 5 Bay Area communities found that doubling residential density reduced VMT per household and per capita 20-30%, and this finding was corroborated with data from other urban regions around the world (Natural Resources Defense Council and the Sierra Club, 1991). A simulation by MTC in the Bay Area found that increasing residential density and jobs-housing balance near to passenger rail stations produced the lowest levels of emissions per capita [corrected by us] and lower emissions in areas adjacent to the region. The models were not operated correctly, however, because no feedback of congested travel times was done, and so the results may be biased (MTC, 1990, ABAG 1990).

An analysis of Bay Area data showed that increased residential density decreased VMT per capita. Unfortunately, the densest areas also were served by rapid rail transit and so the two effects cannot be disentangled. Looking at the districts with good transit service, however, still shows a strong relationship between density and VMT. Also, looking at the districts with poor transit service shows this same slope, but more weakly (Harvey and Deakin, 1990).

One simulation produced counterintuitive results. The Denver region studied density increases near rail transit lines and the result was that VMT was reduced only 1% per capita, but CO levels increased somewhat. This simulation had several acknowledged problems: the density-increase corridors were 2 miles wide, which is way too far to walk to rail or bus; no good feeder system was used; too many jobs were placed in the corridors and an imbalance was created; most transit VMT was on buses in traffic, a poor competitor to the auto; and no pricing policies were used (May and Scheuemstuhl, 1991).

To conclude regarding land use policies, jobs-housing balance (land use mix) seems to not be very effective, unless as part of a density policy. Density increases seem to be effective in reducing VMT and emissions and energy use, especially in conjunction with travel pricing, not building more freeways, and major improvements to transit, especially exclusive guideway transit.

Pricing Policies

An international comparison of models testing TDM policies found that auto costs had to rise by 300 % to reduce VMT by about 33 % . If accompanied by density increases, better transit speeds, and worse auto travel speeds, pricing was more effective. Since the work trip is so unresponsive to price increases (demand is inelastic), good transit service to work centers is needed. Parking charges must be regionwide or, better yet, nationwide, to deter households from moving from the CBD to the suburbs or from one urban region to another. Increasing auto operation costs will increase transit travel to work, especially if good radial service (to the CBD) is available. It will also increase walking to local retail centers. Increasing auto purchase costs also works well, as autos seem to be used for about the same amount of VMT annually in various countries, regardless of household incomes and location. Urban growth boundaries have only a small additional effect in reducing travel (Webster, Bly, and Paulley, 1988).

Road and travel pricing have been advocated by economists for decades. One recent review of the literature shows the large welfare savings possible from road charges, but concludes that these policies are infeasible politically and so recommends efficient levels of parking pricing, efficient truck weight fees, transit subsidies, and bus-only and HOV lanes

(Morrison, 1986). Another recent review finds that congestion is not inefficient and that economic efficiency requires HOV or bus-only lanes to speed up local and express bus transit, more rail transit, and toll roads, as well as free roads, all in order to improve competition among modes (Starkie, 1986).

A comprehensive review of congestion charging mechanisms for roadways found that indirect charges, such as parking charges, fuel taxes, area licensing, and vehicle purchase and license taxes are not efficient in reducing congestion and travel costs. Peak-period road pricing is needed, supplemented by parking taxes. Automatic vehicle identification (AVI) makes tolling less costly than tollbooths (Hau, 1992). Another recent analysis recommends peak-period road pricing and parking pricing (Downs, 1992), to relieve congestion.

A review of congestion charges in Europe (Jones, 1992) states that roadway and downtown cordon tolls are being investigated in Greece, Sweden, the U.K., and the Netherlands. One conclusion of interest to California is that peak-period road tolls are more likely to spread peaks and suppress trips than to cause a switch in mode in low-density urban regions with poor transit service. If densities are high, good transit service is available, and road charges are high, mode switching becomes the prevalent response. Car-pooling use rises only when pools are exempted from tolls. Support for tolls increases substantially if the avowed purposes of the tolls include safety and environmental quality.

Mogridge (1986) issued a proviso for large cities with well-developed transit systems. Tolling road travel or parking will not reduce auto travel, because of unmet demand for auto travel by transit users. Charging autos simply shifts wealthier travellers to auto and less-wealthy ones to transit and mode shares and speeds are not affected. This equilibrium situation only exists where transit travel times are roughly equal to auto travel times, a situation that occurs only in very large urban areas. We note that increasing the costs for all forms of travel, of course, would reduce VMT.

A simulation of pricing policies in Southern California found that VMT could be reduced by about 12 % and pollutants by about 20% with a peak-period congestion charge of $0.15/mi., employee parking charges of $3/day, retail and office parking charges of $0.60/hr., emissions X mileage fees averaging $1 10/yr., and deregulated transit services (which accounted for about 2 percentage points of the reductions) (Cameron, 1991).

Other studies show 20-30% reductions in commute trips to actual sites, when employees pay fully for their parking (Willson and Shoup, 1990). A simulation in the Bay Area found that eliminating parking subsidies to workers would reduce commute trips 25-50%, with the high values in the most dense CBDs (MTC, 1990). Another MTC study showed that pricing measures could reduce VMT by 15 % in 5 years. The policies were parking charges as per the Southern California study, smog fees averaging $125/yr., a fuel tax of $2/gal., and unspecified congestion pricing (MTC, 1990). Shoup (1992) argues that eliminating employee parking subsidies will create growth in CBDs and other employment centers, increase infill developments on small, “leftover” parcels, and reduce transit ridership peaks. All of these changes increase the efficiency of transit and transportation in general.

We consider only peak-period and all-day road pricing in this paper, not cordon charges. Such charges would reduce travel, congestion, travel costs, ozone precursor emissions (NOX, ROG), particulates, and energy consumption. CO hotspots would be slightly reduced, depending on local situations. Cordon charges, levied upon entering the CBD, would be more effective in reducing CO. Such charges are very effective in Singapore (Jones, 1992) and are being studied by large European cities. We do not consider cordon pricing, because of its poor reception in the U.S. and because high-quality transit service is needed to make it effective.

We do not consider the equity effects of tolls in this phase of our research. We note, however, that several studies have shown that tolls can benefit all income groups (Small, 1983; Small, Winston, and Evans, 1989). A recent paper develops a program for spending the revenues that would be generated by the Southern California pricing policies suggested by Cameron (1991) and shows that all commuters benefit financially, due to the tax rebates and transit improvements (Small, 1992).

The conclusion regarding pricing is that it is effective, except in very large urban areas with excellent transit service, where pricing auto use at peak periods may not reduce VMT.

By way of integrating the discussions of pricing and land use measures, we note that cold starts account for the majority of HC emissions in most large urban areas and so the short trip should be a focus of TDMs. Transit provision and peak-period auto pricing may reduce work trip VMT, if land uses are concentrated around rail stations. The shopping trip and social trip can be shifted from the auto to walk, bike, or shuttlebus, if land use mix and density are sufficient, sidewalks and bike lanes are provided, and if shuttlebuses are also provided. We conclude that all of these policies should be simulated in an attempt to reduce VMT, energy consumption, and CO2 emissions and to reduce cold starts and CO and HC emissions.

MODEL DESCRIPTION

Overview

The tool for this research is the adopted Sacramento Regional Transit Systems Planning Study travel demand model developed in 1989 for the Sacramento region. This travel demand model includes all the submodels that exists in a typical regional UTPS model. The submodels are explained in detail in subsequent sections. The submodels are;

- A linear regression trip generation model
- A trip distribution gravity model
- A multinomial logit mode choice model (for HBW trips only)
- An all-or-nothing assignment (for transit and an equillibrium assignment for roadways.

The objective here has been to maintain the official (UMTA-approved) model set that has been adopted by Sacramento RT but to vary system characteristics such as capacity, headways, travel cost, highway and transit configuration and attributes, land use distribution, and other related characteristics that would in turn have an effect on travel.

MINUTP runs were made for each of the alternatives and the resulting travel parameters were then compared. All future year alternatives are based on the 2010 No-Build scenario thus each of the alternatives were compared to 2010 No-Build. Feedback of assigned travel impedances to the trip distribution step was done and the results were compared to the runs that fed assigned impedances only to the mode choice step (the Sacramento RT method).

1. Description of the Modeled Area :

The study area was that of the Sacramento Regional Transit (RT) Systems Planning Study of 1990. The area covers the former SACOG transportation study area and covers most of the residential and employment distribution for greater Sacramento. Note that this area of study has been changed since 1990. This fact will be taken into consideration when modeling is done by us in the future using SACOG's new land use and other related data. The area encompassed by the Systems Planning study covers all Light Rail guideway alignment alternatives and other major transportation facilities and thus is sufficient for our studies.

All Base Year freeway and highway system characteristics represent conditions existing for the year 1989. The No-build 2010 alternative represents the land use growth since 1989 without any new major transportation facilities. All other alternatives, including expansion of Light Rail, were based on the year 2010 No-Build alternative. Figure 1 shows the general area that the studies covered.

No changes were made to the Systems Planning Study analysis zone system. The same SACOG minor zones were used since changes would involve revising a lot of other input data as well as recalibration of the whole model. The same applies to the downtown area, where in the Systems Planning Study the SACOG minor zones were split into much smaller zones to represent accurately walk-to-transit accessibility (DKS Associates, 1990). The zone system used is sufficient for our study purposes since we are looking at the systemwide characteristics and comparing alternatives based on the same area. The downtown zone map is shown in Figure 2. In the Systems Planning Study zones were not subdivided in areas other than the downtown

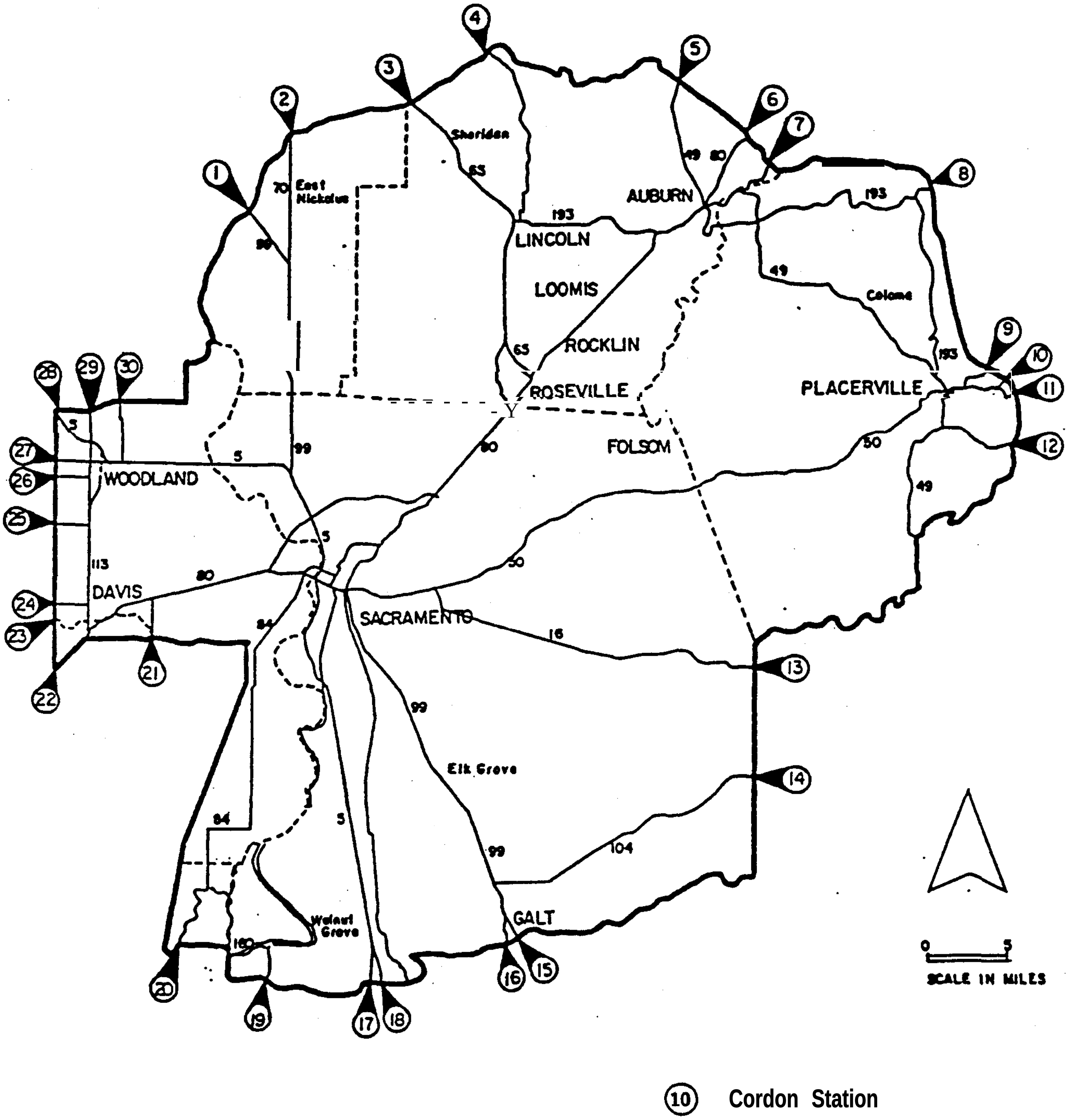

Figure 1
SACOG MODEL AREA and
CORDON STATIONS

SOURCE: REPRODUCTION FROM "SACRAMENTO SYSTEMS PLANNING STUDY", BY DKS & ASSOC., 1990.

Figure 2
RT System Planning Study
DOWNTOWN ZONE SYSTEM

Source: "Sacramento Systems Planning Study", By PARSONS. 1990

area, to reduce data manipulation work.

The SACOG network has 30 external zones or cordons and this was maintained by us. External zones are those zones which serve as the gateway for travel into or out of the study region. They are usually the termination points of major freeway and highway links at the edge of the study area. The Systems Planning Study has 31 external stations and 781 traffic analysis zones (TAZs) and these zones were maintained in our study.

2. Network Characteristics :

All freeways, freeway ramps, expressways, major arterials and collectors coded from the study area were maintained. These transportation facilities are represented as links in the MINUTP network each with their specific characteristics. The characteristics of the links in the System Planning Study remained the same and each type of highway facility is differentiated by its capacity class and speed class. The links are segmented and are connected together by nodes that represent intersections or turning points since only straight lines can be represented in the network. Even though only straight links can be coded, actual distances are assigned to each corresponding link, thus accuracy of the travel distance on a link is maintained. The speed classification and capacity classification of all highway links were maintained. This was done to maintain consistency in the modeling process from which comparative inferences could be made from past modeling practices and results.

The study area of each traffic analysis zone is represented by “centroids” which are nodes in the network from which travel takes place. These centroids are connected to the roadway nodes by links termed “centroid connectors. " These centroid connectors cumulatively represent the minor roads and uncoded collectors that link the centroid to the rest of the highway system. The centroid connector distances are variable and are dependent on the size of the zone and the distance from the centroid to the nearest coded highway link. These enable the model to represent the driving distances from the centroid to the closest highway node more accurately (Parsons, 199 1).

No changes were made to the 1990 Systems Planning Study transit network. The transit network developed was based on conditions and lines existing for the year 1989 (Base Year). The transit network included transit lines operated by agencies other than Sacramento RT and also included a separate A.M peak period and off-peak period transit network (Parsons, 1991). This was done for the purpose of proper mode split during the peak and non-peak periods. Zonal walk-to-transit accessibility measures were also included in the Systems Planning Study. Transit operating speeds and other characteristics were maintained the same throughout the alternatives that were studied. For our studies the transit alternative that was used was the Alternative 8 of the Sacramento Systems Planning Study. The alternatives that were developed for the Sacramento Systems Planning Study are described in detail in Appendix A.

3. Land Use and Socioeconomic Data :

1989 Land Use Data

The updated 1989 and year 2010 land use and socioeconomic data were used. The 1989 land use data were estimated from the 1984 SACOG land use dataset by extrapolation. The procedure employed in the estimation of the 1989 land use data is shown in Appendix B. There is an ongoing effort to improve the reliability of the 1989 land use information by the local planning agencies. This should be kept in mind when comparison is done with future models and land use data sets. For example, the SACOG 1991 regional transportation plan was evaluated using a somewhat different set of land use data. Land use and socioeconomic data were based on the SACOG minor zones except for the downtown area where the land use data used were disaggregated based on the Sacramento city land use map. The variables that are included in the land use and socioeconomic data files are:

- Number of single-family dwelling units
- Number of multifamily dwelling units
- Number of acres in minor zone
- Amount of retail employment
- Amount of non-retail employment
- Total employment
- Median household income (expressed in 1979 dollars)

2010 Land Use Forecast

The 2010 land use data for the Systems Planning Study had been obtained from SACOG's forecast of land use for the whole region for that year. The forecasts that had been allocated to the downtown area are based on the same percentage allocations to that of the 1989 disaggregated zones (Zones were divided into smaller zones and the land use adjusted and forecasted accordingly).

Auto Ownership Stratification

The number of household or dwelling units at the zonal level is stratified based on household auto ownership. The auto ownership categories for the Systems Planning Study are:

- Households with 0 autos
- Households with 1 auto
- Households with 2 or more autos

4. Trio Generation :

This is the first step in the 4 step UTPS modeling process. MINUTP develops zonal productions and attractions from the land use file which contains zonal households that have been stratified by car ownership, retail and non-retail employment, and special generators based on the ITE trip generation tables.

In a trip generation process, each one-way trip has two trip ends. Trip Productions are the home ends of trips regardless if the trip is to or from home and is also defined as the origin ends for all other trips. Trip Attractions are the non-home ends of home-based trips and the destination end for all other trips.

The trip purposes that have been incorporated in this model are as follows:

- Home-Work (trip origin at home and ending at work)
- Home-Shop (trip origin at home and ending at shop)
- Home-Other (trip origin at home and destination at any other place except shop or work)
- Other-Work (trip origin at any other place except home and ending at work)
- Other-Other (trip from any other place other than home and ending at any other place other than shop or work)

In the Systems Planning Study, the trip generation model is based on the 1968 Sacramento Area Transportation Study (SATS) that had been developed from a 1968 survey data set. Production rates from the 1968 SATS trip generation model, the 1984 SACOG Metro Study, and the 1990 RT Systems Planning Study model are shown in Table 4.1. Changes were not made to the production rates and the systems planning study trip rates were maintained in all alternatives. As we can see, there has been considerable changes in the trip rates over the years based on the availability of household trip data. Basically the trip production rates have been recalibrated (though without using any new household trip data) to reflect 1989 land use and travel conditions. Further information on these changes can be obtained from the Travel Model Development draft report (Parsons, 1990). Table 4.1 shows trip production rates stratified based on household car ownership for each of the 5 trip purposes. Table 4.4 shows trip generation rates for households stratified by car ownership in comparison to the NCHRP Report 187 and UMTA 1978 rates. For our comparative study, the rates adopted are sufficient even when the rates that were used are based on 1978 average trip rates.

In the RT systems planning study a separate set of trip attraction rates was estimated and calibrated. The rates were based on other metropolitan areas trip rates. Table 4.5 shows the systems planning study trip attraction rates, production rates and total trip rates for both household and employment.

In the RT Systems Planning Study, trip generation adjustments were used for:

- Colleges
- Hospitals
- Sacramento Metropolitan Airport

Table 4.6 shows the daily person-trips that have been used in the subsequent modeling processes for the special generators.

External trips are those trips that are generated by the gateway zones. The gateway trips have been split into the 5 trip purposes in the RT systems planning study and this was maintained.

5. Trip Distribution :

The trip distribution process uses the trip production and attraction data developed in the trip generation stage to distribute trips to the 812 zones using a standard gravity model equation which distributes the trip productions from each zone to the attractions in all zones, based on the number of attractions in each zone, an impedance matrix generated prior to trip distribution, and a set of friction factors (COMSIS, 1991).

In our case, the travel impedance matrix is the zone-to-zone travel times calculated in a step prior to trip distribution. It is calculated as the shortest time path for links along a path between any two zones and accumulating the travel time of the links along the path.

The travel impedance matrix was generated initially using uncongested speeds and then a feedback process was employed by us where congested speeds from the traffic assignment stage were used. Because this protocol departs from the Systems Planning Study methods, the feedback process is explained below in the Methods section. In the RT Systems Planning Study, intrazonal travel times were generated by estimating the average travel time to adjacent traffic analysis zones. Terminal times were added to each zone-to-zone travel time, to represent access time to automobiles.

TABLE 4.1

Comparison of Household Person Trip Generation Rates

	Single Housing Units			Multiple (and Group) Housing Units			Average of all Households	
Trip Type	Zero Vehicles	One Vehicle	Two + Vehicles	Zero Vehicles	One Vehicle	Two + Vehicles	Trips	%
Original SATS Model								
Home-Work	.161	1.285	2.187	.118	1.170	1.954	1.64	16.5
Home-Shop	.182	1.483	1.941	.151	.961	1.377	1.49	15.0
Home-Other	.562	3.452	5.264	.436	2.242	3.482	3.85	38.7
Total Home-Based	.905	6.220	9.392	.705	4.373	6.813	6.98	70.2
Non-Home-Based[1]	.177	2195	3.946	.204	2.195	3.799	2 %	29.8
TOTAL	1.082	**8.415**	**13.338**	.909	**6.568**	**10.612**	9.94	**100.0**
Metro **Study** Model								
Home-Work	.171	1.362	2.447	.125	1.240	2.207	1.81.	15.8
Home-Shop	.196	1.600	2.242	.163	1.038	1.584	1.68	14.7
Home-Other	.607	3.728	6.068	.471	2.420	3.000	4.35	38.0
Total Home-Based	.974	6.690	10.757	.759	4.698	7.781	7.84	68.5
Non-Home-Based[1]	.206	2546	4.891	.236	2.546	4.692	3.61	31.5
TOTAL	**1.180**	9.236	**15.648**	.995	7.244	12.473	**11.45**	**100.0**
RT Model								
Home-Work	0.3	1.8	2.2	0.2	1.2	1.8	1.75	22.0
Home-Shop	0.6	1.0	1.5	0.4	0.9	1.2	1.19	14.8
Home-Other	0.8	3.0	4.3	0.4	2.5	3.8	3.38	42.1
Total Home-Based	1.7	5.8	8.0	1.0	4.6	6.8	6.32	78.9
Non-Home-Based[1]	0.3	1.2	2.4	0.3	0.9	2.0	1.70	21.1
TOTAL	2.0	7.1	10.4	**1.3**	**5.2**	**8.8**	802	**100.0**

1. For SATS and Metro Study models, total non-home-based attractions are calculated from household rates and are then allocated to zones based on attraction regression equation estimates (sa Table 6). RT's model uses attraction rates from Table 9 for both calculating and allocating total non-home-based trips. Household rates under RT model for non-home-based trips are listed above for comparison only.

Source: "Sacramento Systems Planning Study", By PARSONS. 1990

TABLE 4.2

SATS Model & Metro Study
Trip Attraction Equations

Home-Work: $Aj = 34.31567 + 1.,39974\ TE$

Home-Shop: $Aj = -11.03247 + 10.86557\ [RE/(1 + .05\ (TE/Acres))]$

Home-Other: $Aj = 146.3562 + 0.66554\ pop + 3.86057\ RE + 0.34734\ NRE$

Other-Work: $Aj = 33.20018 + 27.48297\ (\sqrt{NRE + 64} - 8) + 0.83077\ RE$

Other-Other: $Aj = 3.86670 + 217.28723\ (\sqrt{RE + 49}\ 7) + 0.21416\ Pop$

Where: Aj = Attraction Factor for Zone j
RE = Retail Employment in Zone j
Pop = Population in Zone j
TE = Total Employment in Zone j
NRE = Non-Retail Employment in Zone j
Acres = Number of Acres in Zone j

TABLE 4.3

Comparison of Production/Attraction Balance - 1984 Trips

	Calculated Trip Ends			
Trip Purpose	Productions	Attractions	Percent P's	P/A
SACOG Model (Metro study)				
Home-Work	829,301	677,450	14.6	1.22
Home-Shop	765,702	706,082	13.5	1.08
Home-Other	1,969,148	1,375,293	34,8	1.43
Other-Work	421,952	278.1%	7.5	1.52
Other-Other	1,582,161	922,202	28.0	1.72
Internal-External	92,008	0	1.6	--
External-Internal	0	87.225	0.0	--
TOTAL	5,660,272	4,046,448	100.0	1.40
RT Model[1]				
Home-Work	766,594	761,088	22.0	1.01
Home-Shop	515,255	478,950	14.7	1.08
Home-Other	1,465,205	1,397,958	41.9	1.05
Other-Work	222,191	222,191	6.4	1.00
Other-Other	525.913	525.913	15.0	1.00
	3,495,158	3,386,100	100.0	1.03

---

1. Trips are calculated using 1984 land use data for comparison with SACOG modd. RT model was calibrated using 1989 land use data. RT modd does not use "Internal-External" and "External-Internal" as trip "purposes" but rather incorporates those trips into the other trip purposes.

Source: "Sacramento Systems Planning Study", By PARSONS. 1990

TABLE 4.4

Comparison of Household Person Trip Rates

Model/Source	Daily Person Trips per Household by Auto Ownership			
	Zero Vehicles	One Vehicle	Two + Vehicles	Total
SATS Model	1.0	7.6	12.9	9.9
SACOG Metro Model	1.1	8.3	15.2	11.5
NCHRP Report 187[1]	3.1	6.5	10.0	7.6
UMTA 1978 Handbook[2]	1.8	6.9	11.9	8.1[3]
RT **Model**	1.6	6.3	10.2	8.0

Model/Source	Percentage of Daily Person Trips by Trip Purpose		
	Home Based-Work	Home Based-Other	Non-Home Based
SATS Model	16.5	53.7	29.8
SACOG Metro Model	15.8	52.7	31.5
NCHRP Report 187[1]	25.0	54.0	21.0
UMTA 1978 Handbook[2]	24.6	57.2	18.2
RT Model	22.0	56.9	21.1

---

1. Based on origin-destination surveys of urbanized areas with a population of 750,000 to 2,000,000. Source: National Cooperative Highway Research Program Report 187 "Quick Response *- Urban Travel Estimation Techniques and Transferable Parameters," 1978.*
2. Based on transportation studies from major urbanized areas. Source: ***"Characteristics of Urban Transportation Demand - a Handbook for Transportation Planners,"*** UMTA, 1978.
3. Calculated using average percentages of households by auto ownership from urbanized areas with population of 750,000 to 2,000,000.

Source: "Sacramento Systems Planning Study", By PARSONS. 1990

TABLE 4.5

Combined Daily Person Trip Production and Attraction Rates - RT Model

Trip Type	Single Housing Units			Multiple Housing Units			Employment	
	Zero Vehicles	One Vehicle	Two + Vehicles	Zero Vehicles	One Vehicle	Two + Vehicles	Retail	Other
Productions								
Home-Work	0.34	1.80	2.20	0.21	1.20	1.80		
Home-Shop	0.60	1.00	1.50	0.40	0.90	1.20		
Home-Other	0.80	3.00	4.30	0.60	2.50	3.80		
Other-Work							1.40	0.30
Other-Other	0.10	0.10	0.10	0.10	0.10	0.10	4.20	0.40
Total Productions	1.84	5.90	8.10	1.31	4.70	6.90	5.60	0.70
Attractions								
Home-Work							1.70	1.70
Home-Shop							6.00	
Home-Other	0.30	0.80	1.20	0.20	0.50	0.70	3.50	2.00
Other-Work							1.40	0.30
Other-Other	0.10	0.10	0.10	0.10	0.10	0.10	4.20	0.40
Total Attractions	0.40	0.90	1.30	0.30	0.40	0.80	16.80	4.40
TOTAL TRIPS	2.24	6.80	9.40	1.61	5.30	7.70	22.40	5.10

Source: "Sacramento Systems Planning Study", By PARSONS. 1990

TABLE 4.6

1989 and 2010 Daily Person Trips for Special Generators

	Zones TAZ	Daily Person Trips[1] 1989	 2010
UC Davis	81	19,180	27,600
Sierra College	191	8,881	18,550
American River College	383	23,366	25,265
California State University	514	33,492	47,143
Sacramento City College	661	10,899	10,889
Consumnes River College	720	16,925	22,400
Kaiser Hospital	352	9,638	10,100
American River Hospital	368	649	681
Mercy San Juan Hospital	436	501	554
Sutter Memorial Hospital	467	2,374	2,986
Mercy General	470	1,627	1,600
Sacramento Medical Center	478	2,026	2,100
Sutter General Hospital	774	3,349	3,400
Sacramento Metro Airport[2]	285	23,734	50,378

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1. Except as noted, these trips an added to trips generated using standard trip rates.
2. These trips replace those calculated using standard trip rata.

Source: “Sacramento Systems Planning Study”, By PARSONS. 1990

In the trip distribution model, the friction factors represent the likelihood of travel between zones based upon the impedance between the zones. In essence it is the effect of spatial separation on trip interchange between zones which are t_{ij} apart.[Finney, 1972] The friction factor will approximate a function called the deterence function which originally was chosen as $1/t^n$ where n varies with t but improved fits have been used lately.[Potts & Oliver, 1972] In general there is one friction factor for each one minute increment of travel time. A specific deterence function for the friction factor estimation was not not provided in the RT Systems Planning Study report. The friction factors that were used in the Systems Planning Study are based on those used in the Seattle, Washington region, which was assumed to have similar trip length characteristics to the Sacramento region. Five sets of friction factors have been developed, one for each trip purpose. Table 5.1 is the reproduction of the friction factor table that was used in the Systems Planning Study. The same friction factors have been used for both the 1989 base year and the 2010 future year forecasts. All the alternatives in our study are based on the 2010 No-Build scenario and the friction factors were maintained. The friction factors were not calibrated for the future year because of the presumption that the relative propensity for making trips of different lengths will not change with time.

The trip distribution model is shown below.

$$T_{i,j} = \frac{P_i \, A_j \, F(t_{i,j}) \, K_{i,j}}{\Sigma_{x=1,n} [A_x \, F(t_{i,j}) \, K_{i,j}]}$$

$T_{i,j}$ = number of trips from zone i to zone j
P_i = total number of trips produced in zone i
A_j = attractions in zone j
$F(t_{i,j})$ = friction factors between zone i and j
$K_{i,j}$ = zone to zone adjustment factor
$t_{i,j}$) = travel times between zone i and j
i = designation of production zone
j = designation of attraction zone
x = designation of all zones

The denominator is the sum of numerators for all attraction zones relative to zone j and is sometime referred to as the accessibility index for zone i. The attractions for each zone are then calculated based on the “pro rata share” of all zone i productions based upon its share of the index.

TABLE 5.1 : GRAVITY MODEL FRICTION FACTORS

Time [Minutes)	Home-Work	Home-Shop	Home-Other	Other-Work	Other-Other
1	17000	120000	35000	34000	34000
2	16500	118000	31500	28000	28000
3	14200	86000	25000	21200	21200
4	11600	56000	18400	15200	15200
5	8900	37000	13000	9900	9900
6	6300	24500	9500	6300	6300
7	4400	15500	7100	4450	4450
8	3200	9700	5300	3150	3150
9	2400	6000	3850	2300	2300
10	1900	3350	2750	1700	1700
11	1500	2250	1900	1260	1260
12	1200	1500	1250	960	960
13	980	1000	950	730	730
14	810	720	710	560	560
15	690	500	530	440	440
16	590	350	410	340	340
17	500	250	315	265	265
18	425	200	250	210	210
19	365	150	200	172	172
20	318	115	160	135	135
21	283	88	130	110	110
22	250	70	107	91	91
23	220	56	91	77	77
24	196	46	75	64	64
25	174	38	64	55	52
26	156	32	55	47	47
27	140	27	47	40	40
28	128	22	41	34	34
29	115	19	34	30	30
30	104	16	30	26	26
31	92	14	26	22	22
32	83	12	23	20	20
33	74	10	20	17	17
34	66	9	18	16	16
35	58	7	16	14	14
36	53	6	14	12	12
37	48	6	13	11	11
38	44	5	12	10	10
39	40	4	10	9	9

Source: “Sacramento Systems Planning Study”, By PARSONS. 1990

TABLE 5.1 : GRAVITY MODEL FRICTION FACTORS

Time (Minutes)	Home-Work	Home-Shop	Home-Other	Other-Work	Other-Other
40	35	4	9	8	8
41	32	3	9	8	8
42	28	3	8	7	7
43	25	3	7	6	6
44	23	2	7	6	6
45	21	2	6	5	5
46	19	2	6	5	5
47	17	2	5	4	4
48	16	1	5	4	4
49	14	1	4	4	4
50	13	1	4	3	3
51	12	1	4	3	3
52	10	1	3	2	2
53	9	1	3	2	2
54	8	1	3	2	2
55	7	1	3	2	2
56	7	1	2	2	2
57	6	1	2	2	2
58	6	1	2	2	2
59	5	1	2	1	1
60	5	1	2	1	1
61	4	1	2	1	1
62	4	1	2	1	1
63	4	1	1	1	1
64	3	1	1	1	1
65	3	1	1	1	1
66	3	1	1	1	1
67	3	1	1	1	1
68	2	1	1	1	1
69	2	1	1	1	1
70	2	1	1	1	1
71	2	1	1	1	1
72	1	1	1	1	1
73	1	1	1	1	1
74	1	1	1	1	1
75	1	1	1	1	1
76	1	1	1	1	1
77	1	1	1	1	1
78	1	1	1	1	1

Source: “Sacramento Systems Planning Study”, By PARSONS. 1990

TABLE 5.1 : GRAVITY MODEL FRICTION FACTORS

Time (Minutes)	Home-Work	Home-Shop	Home-Other	Other-Work	Other-Other
79	1	1	1	1	1
80	1	1	1	1	1
81	1	1	1	1	1
82	1	1	1	1	1
83	1	1	1	1	1
84	1	1	1	1	1
85	1	1	1	1	1
86	1	1	1	1	1
87	1	1	1	1	1
88	1	1	1	1	1
89	1	1	1	1	1
90	1	1	1	1	1
91	1	1	1	1	1

Source: “Sacramento Systems Planning Study”, By PARSONS. 1990

6. Mode Choice :

New mode choice models were developed for the 1989 Systems Planning Study based on the 1989 RT ridership and on-board surveys. Mode choice models were developed for two sets of trip purposes, home based work trip and non-work trips.

The home based work trip mode choice model is a multinomial **logit** (MNL) model. The principle behind the MNL model is that the model assigns a probability to using a particular mode based upon the utility or attractiveness of that mode in relation to the sum of the attractiveness measures (utility) of all the modes available. MNL models are expressed as an exponential function of the utilities or attractiveness measures involving level of service, socioeconomic characteristics, and other variables.

The mathematical expression for the model is shown below.

$$P_{g,i} = \frac{\exp[U_{g,i}(x_{g,i})]}{\sum_{g,m}\exp[U_{g,m}(x_{g,m})]}$$

where:

$P_{g,i}$	is the probability of a traveler from group g choosing mode i
$U_{g,i}(x_{g,i})$	is the utility (or attractiveness) measure of mode i for travelers in group g
$\sum_{g,m}$	is the sum of all utilities of modes m
$U_{g,m}(x_{g,m})$	is the utility of modes m for travelers in group g

The utility function for each mode is defined as follows:

$$U_{g,m}(x_{g,m}) = a_m + b_m LOS_m + c_{g,m} SE_g + d_m TRIP$$

LOS,	is a set of variables (in-vehicle time, out-of-vehicle time, drive access time, auto operating cost/transit fare and parking cost) describing levels of service provided by mode m
SE_g	is a set of variables (auto ownership categories) describing the socioeconomic characteristics of group g
TRIP	is a set of variables describing characteristics of the trip (CBD-orientation, etc)
b_m	Coefficients of LOS,
$c_{g,m}$	Coefficients of $SE_{g,m}$ for group g with respect to mode m
d_m	Coefficients of variable TRIP for each mode m
a_m	is a constant specific to mode m that captures the overall effect of any significant variables that are missing from the expression (such as comfort, safety etc.)

In the Systems Planning Study the mode choice model predicts mode split for the following mode choices:

- Walk to Transit
- Drive to Transit
- Drive Alone
- 2+ Person Auto

- 3+ Person Auto

Walk to Transit and Drive to Transit have been included as separate modes in the Systems Planning Study to reflect the tradeoffs between the access modes. The procedure that was used in MINUTP to develop and model the access modes or links are described in Section 8 below.

Most of the coefficients of the mode choice model of the RT systems planning study were obtained from comparative studies of other models from other large urban areas in the U.S. Midrange values from models of other urban areas had been used for the level of service coefficients (these were not estimated by SACOG). The LOS coefficients selected for the HBW mode choice model were as follows.

● In-vehicle Time (mins)	-0.025
● Out-of-vehicle Time (mins)	-0.050
● Drive access time (mins)	-0.025
● Auto operating cost	13¢/mile
● Parking Cost (2.5 x coeff of auto operating cost)	

The home based work mode choice model is further stratified into car ownership categories. The model was not re-estimated or the coefficients adjusted for our study but considered adequate enough for comparative analysis purposes. Changes were only made in the auto operating cost variable where cost per mile were varied to study various pricing scenario. Table 6.1 shows the coefficients that were estimated for the home based work mode choice model. Changes made in the auto operating cost and addition of other pricing variables are described below.

The non-work trip mode split estimation process involves factoring applied to the home based work trip transit shares estimated from the MNL HBW model. These factors were applied to each zone-to-zone interchange that has transit service during the offpeak period. Tables 6.2 through 6.5 show the mode split factors for the non-home based mode split and comparisons of factored mode split with observed transit share.

7. Traffic Assignment :

In MINUTP traffic assignment is done by reading trip files, building paths for those trips, assigning the trips to the links in the paths (accumulating link volumes), and when all trips have been processed, adjusting the link travel times based on congestion and repeating the entire process for the specified number of iterations. The number of iterations that had been used in the Systems Planning Study was 5 and this was maintained in our study.

The path building process involves the use of travel impedances of the links; thus the iterative process is actually a feedback process of congested travel times back into the assignment process. Highway assignment and transit assignment are done separately.

The method used in the highway assignment process is the “equilibrium assignment” process. The equilibrium assignment method assigns trips between two zones to more than one path in each iteration and the trips are shifted between paths for each subsequent iteration until there are no other paths which have a faster travel time. Travel time is adjusted at the end of each iteration based upon congestion of the links comprising each path, using volume-to-capacity ratios based on a set of speed capacity curves included in the assignment module. The speed capacity curves are based on data reported in the 1985 Highway Capacity Manual.

TABLE 6.1

Coefficients in the Home-Based-Work Model

			Modes[2]			Model
Variable’	DA	SR2	SR3+	WTT	DTT	Coefficient
In-vehicle time	x	x	x	x	x	-0.025
Walk time				x	x	-0.050
First wait time < 8 minutes				x	x	-0.050
First wait time > 8 minutes				x	x	-0.025
Transfer time				x	x	-0.050
Auto access time					x	4.025
Auto operating cost/(occupancy x income)	x	x	x		x	-0.100
Parking costs/(occupancy x income)	x	x	x			-0.125
Transit fare/income				x	x	-0.100
CBD indicator, attr (O/l)		x				-0.643
CBD indicator, attr (O/l)			x			-0.139
CBD indicator, attr (O/l)				x		0.295
CBD indicator, attr (O/l)					x	1.678
0 ’Vehicle Household, prod (0/1)		x				2279
0 Vehicle Household, prod (O/l)			x			1.314
0 Vehicle Household, prod (O/l)				x		5.940
0 Vehicle Household, prod (O/l)					x	4.470
1 Vehicle Household, prod (O/l)		x				-2.035
1 Vehicle Household, prod (O/l)			x			-3.431
1 Vehicle Household, prod (O/l)				x		-1.779
1 Vehicle Household, prod (0/1)					x	-3.987
2+ Vehicle Household, prod (O/l)		x				-2.019
2+ Vehicle Household, prod (O/l)			x			-4.068
2+ Vehicle Household, prod (O/l)				x		-2.557
2+ Vehicle Household, prod (O/l)					x	-3.152

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1. Tii are in minutes and costs are in cents (1989 value).

2. "Modes" indicates the alternatives that include each variable in their utility expressions: DA = Drive Alone; SR2 = Shared Ride 2 Occupants; SR3+ = Shared Ride 3+ Occupants; WTT = Walk to Transit; DTT = Drive to Transit

Source: “Sacramento Systems Planning Study”, By PARSONS. 1990

TABLE 6.2

Home-Based Other (HBO) and Non-Home-Based (NHB) Mode Split Factors

	Distance (miles)				
	0 - 2	2 - 5	5 - 10	10 - 15	15 - 20
HBO Factors for Walk to Transit					
0 Auto HH	0.459	0.485	0.423	0.609	0.397
1 Auto HH	0.375	0.394	0.233	0.247	0.091
2+ Auto HH	0.368	0.368	0.221	0.228	0.089
HBO Factors for Drive to Transit					
0 Auto HH	0.134	0.161	0.372	0.181	0.137
1 Auto HH	0.122	0.139	0.251	0.155	0.112
2+ Auto HH	0.247	0.126	0.203	0.171	0.118
NHB Factors for Walk to Transit					
All Auto HH	0.340	0.293	0.176	0.201	0.061
NHB Factors for Drive to Transit					
All Auto HH	0.302	0.236	0.322	0.122	0.063

Source: “Sacramento Systems Planning Study”, By PARSONS. 1990

TABLE 6.3
Comparison of Model Estimates to Observed Transit Persons Home-Based Other Trips

	Walk to Transit	Drive to Transit	Total
"Observed" Transit Person Trips			
0 Auto HH	7,898	163	8,061
1 Auto HH	6,245	495	6,740
2+ Auto HH	5,108	1,130	6.238
Total	19,251	1,787	21,038
"Estimated" Transit Person Trips			
0 Auto HH	7,681	163	**7,844**
1 Auto HH	6,147	493	6,640
2+ Auto HH	5,091	1.128	6,219
Total	**18,919**	1,784	20,703
Percent Difference **between** "Observed" and "Estimated"			
0 Auto HH	-2.7%	0.2%	-2.7%
1 Auto HH	-1.6%	-0.3%	-1.5%
2+ Auto HH	-0.3%	-0.1%	-0.3%
	-1.7%	-0.2%	-1.6%

TABLE 6.4
Comparison of Model Estimates to "Observed" Transit Persons Non Home-Based Trips

	Walk to Transit	Drive to Transit	Total
"Observed' Transit Person Trips			
Total	6,152	819	6,971
"Estimated" Transit Person Trips			
Total	6,256	824	**7,080**
Percent Difference between "Observed" and "Estimated"			
Total	1.7%	0.6%	1.6%

Source: "Sacramento Systems Planning Study", By PARSONS. 1990

TABLE 6.5

Comparison of Model Estimates to Observed Daily Transit Persons Daily Trips for All Purposes

	Walk to Transit	Drive to Transit	Total
"Observed" Transit Person Trips			
Total	44,076	10,101	54,177
"Estimated" Transit Person Trips			
Total	43,593	9,892	53,485
Percent Difference between Total "Observed" and Total "Estimated"			
Total	-1.1%	-2.1%	-1.3%

Source: "Sacramento Systems Planning Study", By PARSONS. 1990

The mode choice model has been structured to read two sets of travel times, one for non-HOV trips and the other for HOV trips. The model assigns travel time based on capacity constrained peak hour assignment to each occupancy alternative and computes the mode shares, recognizing the HOV time savings.

The transit assignment technique is not dependent on any capacity constraints as it is assumed that the transit capacity is adjusted to meet increased demand. Walk access and drive access trips and non-work and work transit trips for peak and off-peak transit networks are assigned separately. If there is more than one transit line between two zones the trips are assigned to the shortest path between the two zones, taking into consideration in-vehicle and out of vehicle times.

8. Transit Modeling :

The transit module has the capability to form transit networks, develop zone-to-zone paths along transit networks, extract level-of-service matrices along transit paths, and assign trips to transit paths (COMSIS, 1991). The transit network generates sets of transit links that have travel times, distance, a valid mode indicator and parallel links for various modes, transit speeds, and transit time slices for each zone-to-zone path. These transit characteristics are generated from the base network, transit line data, and zonal access controls. The base network is the coded MINUTP network that contains all the highway characteristics, the transit links, drive access and walk access links, and the zone access controls.

Zone-to-zone transit paths are selected only if the origin and destination zones have access to transit. Access for an origin zone for walk access trips is represented by a stop node and for drive access trips by a park and ride node (PNR node). Access for a destination zone is by walk trips only and is allowed for all zones by allowing walk trips on the base network links from stop nodes on transit links to any other zone. Note that drive access trips are only valid for the specified zones where a link has been established between the particular zone and the closest PNR node. The bus links are represented by the highway links in the base network whereas for other modes, such as light rail transit, a separate link has to be coded.

The model includes two basic steps:

1. Select zone-to-zone transit paths and write travel impedance matrices for modal split, and
2. Assign transit trips to transit paths (i.e., load the transit network).

9. Overall Model Oneration Methods :

Feedback to Mode Choice Only

In the Systems Planning Study, the congested speed and travel times were estimated for all links at the traffic assignment phase. A loop was used to feed these congested speeds and times back into mode choice. This provided new congested speeds and travel times based on the first estimation. This feedback loop can be repeated for a number of times until the speed and time do not change between iterations (equilibrated values). This partial feedback protocol corrects mode choice for the effects of congestion, but does not correct trip lengths (in the trip distribution step) for these effects. This is a serious flaw when modeling for the purpose of projecting travel and emissions, because trip length is the main determinant of VMT.

Modeling Towards Equilibrated Values

To correct this deficiency, we developed a method for full equilibration. When a driver picks a route to get to his destination, he would select the minimum path based on travel time. Every other tripmaker in the network would be trying to chose his/her quickest route at the same time, thus the first path assigned to a tripmaker would not be their best route after loading the road network. The original path would become congested with the additional tripmakers. The driver then has to go through his choice process all over again. This procedure of selecting the best route is a continuous and dynamic process until there are no better routes. This is when the driver's speed and travel time has reached an optimal value with respect to the assignment of the whole network.

In the modeling process the first path assigned is based on the link speed or travel impedance that is initially coded into the network. In our case, the posted free flow speed is used (uncongested speed). The model than estimates the shortest destination path for each trip based on this speed. The process then proceeds to the trip assignment stage, where at the end of the assignment a new congested speed is calculated, based on the destination choice of all trips estimated at the trip distribution stage. This new congested speed from the assignment stage is fed back to the trip distribution step where a new origin-destination table is created for all trips. The model thus estimates a new destination path for all trips in the model, using new travel times estimated from the congested speeds. This feedback of congested speeds or travel time in a loaded network is done until the new estimated speed does not change any more (i.e. the speed from the assignment stage does not vary after further iterations when congested speed used in trip distribution does not vary with the new congested speed estimated at the assignment level). The travel speeds or times have reached an equilibrated stage with respect to the whole system and all trip makers have no other shortest destination choice to choose from. These feedback process is schematically shown in Figure 9.1.

Feedback Loop in MINUTP

The first model run involves the use of uncongested speed at the trip distribution step, from which a set of origin-destination (O-D) tables are estimated for all zones. The speeds are the numbers initially coded into the network links during the model development process. The modeling process uses these speeds to estimate new speeds and travel times later in the modeling process which better reflect the loaded conditions of the network based on the O-D table generated at the trip distribution level. The new speed and travel time obtained at the end of the modeling process (after assignment) can be very different from that used at the beginning of the model process. Several iterations are needed to obtain equilibrated speeds. The feedback process is very computationally time-consuming and thus 5 iterations were done by us and the average of the 5 plus the initial run is considered as the equilibrated set of values in our modeling process. When the VMT, VHT, VHD etc. are plotted against its **i**th iteration, they converge in a dampening form leading toward a stable set of values.

Feedback to Trip Distribution

In the trip distribution feedback process, the feedback goes to the trip distribution step, as well as to the mode choice step. The principle is the same as that of the mode choice feedback loop. The uncongested times and speeds are used in the initial run. New congested

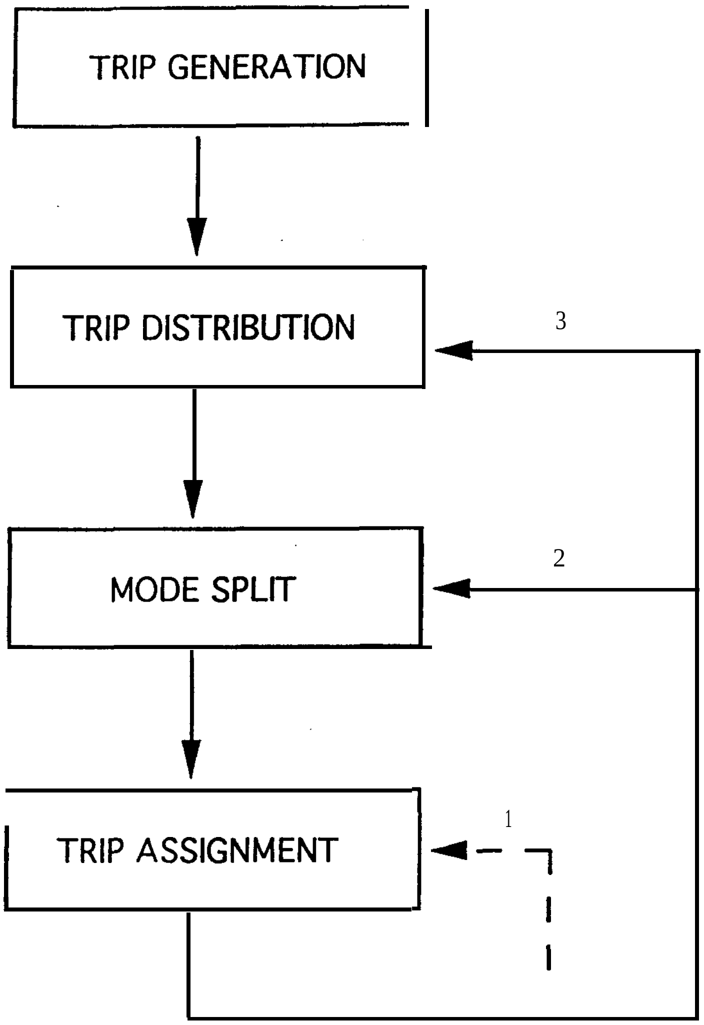


FIGURE 9.1 : FEEDBACK PROCESS BETWEEN UTPS SUBMODELS

1 - **INTERNAL EQUILLIBRIUM** ITERATION OF LINK IMPEDANCE
2 - FEEDBACK OF TRAVEL IMPEDANCE TO MODE SPLIT
3 - FEEDBACK OF TRAVEL IMPEDANCE FROM ASSIGNMENT TO TRIP DISTRIBUTION

speeds and travel times are estimated at the assignment stage and then used in subsequent model runs for the trip distribution step and the new O-D tables are estimated. As described earlier, iterations are done for every single alternative and the equilibrated values estimated. Partial feedback within mode choice is retained, so all model steps use the same travel times.

10. Model Travel Data Outputs

Model parameters were calculated using the adjusted loaded daily road network. The following parameters were calculated:

- Total network vehicle miles traveled **(VMT)**
- Total vehicle hours traveled throughout the network **(VHT)**
- Vehicle hours of delay of the whole network **(VHD)**
- Lane miles of congestion (defined as that which has LOS E and LOS F) and
- Average network speed

These parameters are estimated using the following formulas and procedures:

1. Vehicle Miles of Travel (VMT) = Volume * Distance
2. Total Vehicle Hours(VHT) = (Volume * Distance)/Free Speed
3. Vh.Hr.Delay = Volume * [(Distance/Congested Speed)- (Distance/Free Speed)]
4. Lane Miles of Congestion = Dist. * Number of Lanes (if Link is LOS E-F)
5. Average Network Speed = **VMT/VHT**
6. VHD Reduction = % Difference of vehicle hour of delay of the alternative over year 2010 No Build.

The model also estimates the person trips by trip purpose and vehicle trips by mode.

ALTERNATIVES MODELED

A. Existing Alternatives :

Several alternatives were examined in our study and their system characteristics and person-trip and vehicle-trip shares compared. No changes were made to any input data unless otherwise indicated here. The 1989 base network model, 2010 no-build model, the 2010 HOV scenario, and the Light Rail Alternative 8, all from the systems planning study, were used as a basis for our comparative study. The following are the alternatives that were already developed but rerun for our purposes.

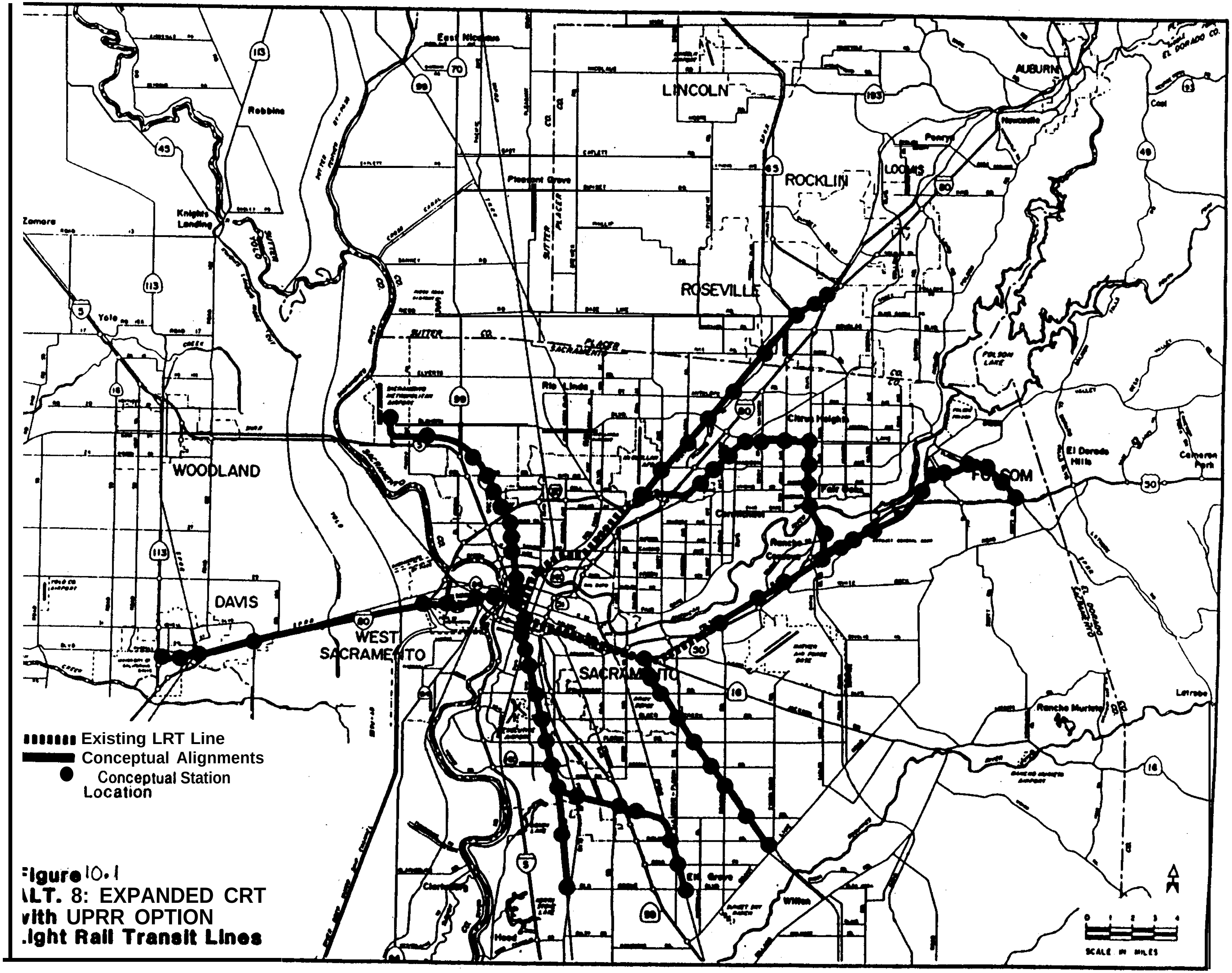
1. 1989 Base Year.
2. 2010 No-Build. Modeled with year 2010 predicted land use data without any major transportation facility improvements.
3. HOV Lanes. A system of existing and proposed HOV lanes on the inner freeways by year 2010.
4. Light Rail Transit Alternative. Alternative 8 of the Systems Planning Study (see Figure 10.1).

B. Automation Alternatives :

1. HOV1 - In this case the HOV lanes are automated and set to 60 mph with a 1 second headway. In the model the headway is reflected by varying the capacity of the links in question. In this case the capacity of the HOV lane was set at 3600 vehicles/hour/lane to reflect the 1 sec headway on the links. All other input files are the same ones used for the HOV scenario.
2. HOV2 - Here the HOV lanes are automated and set to 80 mph with a 0.5 second headway. The headway of 0.5 seconds amounts to a 7200 vehicles/hour/lane capacity. This change was made in all the NETMRG modules in the MinUTP jobstream file. All other files were the same ones that were used for the HOV alternative.
3. Automation Alternative 1 - Partial Automation of the freeway links using the year 2010 no-build alternative. Only the freeway links that have a level of service of worse than E were automated and set to 60 mph and 1 sec headway(i.e. 3600 vehicles/hour/lane capacity). Only one lane in each direction needed to be automated.
4. Automation Alternative 2 - In this scenario all freeway links are automated and set to a speed of 80 mph and 0.5 second headway (i.e. 7200 vehicles/hour/lane). All other operational variables were the same to that which was applied to the partial freeway automation.
5. Automation Alternative 3 - In this scenario all the freeway links are automated and set to a speed of 60 mph and 1 second headway (i.e. 3600 vehicles/hour/lane). All capacity changes were made for the appropriate facility.

In all cases the speed/flow characteristics were adjusted where necessary to reflect the changes in the volume/capacity ratio.

The 2010 No-Build network was the base network for all new alternatives developed for this study unless otherwise stated. Speed increases were made for the automated lanes using the NETMRG module of MINUTP for each specified capacity class and this speed was maintained



▮▮▮▮▮▮▮ Existing LRT Line
▬ Conceptual Alignments
● Conceptual Station Location

'igure 10.1
\LT. 8: EXPANDED CRT
vith UPRR OPTION
.ight Rail Transit Lines

for all cases (i.e. even in the loaded network to reflect the automated speed of the link in question at all times).

C. Land Use and Pricing TDM Alternatives :

The Land Use Intensification alternative and the Pricing alternative are based on the Light Rail Alternative, Alternative 8 of the Sacramento systems planning study. The land use (housing and employment) and zone characteristic (accessibility index) data set were changed for the land use alternative. For the Pricing alternative the zone characteristic (zonal parking costs) data set was altered. All other input data sets were maintained the same. The following describes the two alternatives modeled for the TDM's:

1. Pricing Alternative. Congestion pricing, parking cost increases, and gas tax increase were introduced into the light rail transit alternative.
2. Transit Oriented Development. 2010 land use growth was moved from the fringe areas and areas far from light rail stations into the existing and proposed light rail station locations.

The modeling process for the study of the pricing scenario was based on three travel cost increases. The auto operating cost was increased by 3 cents a mile to reflect an increase in gasoline taxes of $2.00 a gallon. Since the long-run elasticity of demand for travel with respect to fuel costs is about -0.3, due to a shift to higher-mpg vehicles, we entered a fuel tax of $0.60/gallon. Fleet mileage was assumed at 20 gallons per mile and so the per mile cost increase is 3 cents. The congestion pricing was placed at 25 cents per mile for arterials and 50 cents for freeways and applied to HBW trips to (poorly) approximate peak-period trips. The model is for daily trips and does not directly project peak trips. Parking costs were increased to $5.00 a day in the CBD, $3.00 at major employment centers, and $2.00 at all other places.

The TOD alternative involved the use of the LRT network but with considerable changes to the 2010 land use data. Landuse intensification was done around existing and proposed light rail stations based on the systems planning study alternative 8 proposal. The following LRT corridors were identified based on the RT proposal for the shifting of land use growth into the TOD zones.

- Natomas-Airport (From downtown Sacramento northwest to Metro Airport)
- Roseville (Downtown Sacramento northeast to Roseville)
- Folsom (Downtown Sacramento east to Folsom)
- Cal Traction (Downtown Sacramento along the Central California Traction railroad alignment southeast to Grant line road) @ South Corridor (Downtown Sacramento south to Elk Grove community)
- Davis (Downtown Sacramento through West Sacramento, west of City of Davis to the U.C. Davis campus paralleling I-80)
- Auburn-Greenback-Sunrise corridor (LRT loop from Watt Ave. east along Auburn to Greenback and then south along Sunrise to the Folsom line)

All employment and household growth for the year 2010 from the surrounding rural edges was shifted into the TOD zones. About half of the employment growth from the areas adjacent to the corridors specified above was shifted into the TOD zones. This was done to maintain a reasonable jobs/housing balance in the TOD zones. Two thirds of housing growth from the zones adjacent to the corridors was moved into the TOD zones. Only 25% of the housing growth in the zones adjacent to the Natomas corridor was shifted to the TOD zones of its LRT corridor. This was done to maintain a reasonable housing density in those TOD zones. The shifting of households and employment was done keeping in mind the restrictions in some of the TOD zones involving no growth due to flooding problems and due to the 65 -decibel noise boundary around Mather Air Force Base. Due to the high density of housing and employment along the Roseville corridor only half of the growth in zones adjacent to the corridor were shifted.

A quarter-mile radius was used to identify the TODs surrounding the stations and all zones falling mostly within this perimeter were used. The transit accessibility indexes for these zones were converted to 100% to reflect total accessibility of all households and employment to transit. The shifted households were then distributed among the car ownership stratifications to maintain the control totals for each car ownership category and total trips for the whole model region. Once the housing and job growth were moved into the TOD zones, they were then shifted between TOD zones along each corridor to maintain reasonable jobs-housing balance and density. A total of approximately 70% of single-family housing and about 65% of multifamily housing growth were shifted into the TOD zones from the non-TOD zones and from within this total approximately 7% of the single-family and 6% of the multifamily housing growth were shifted into the downtown area. Approximately 78% of retail employment growth and 73% of non-retail employment growth were shifted from all other zones to the TOD zones. No retail or non-retail employment were shifted into the downtown area and this was done in order to maintain the downtown jobs/housing balance. No shifts were made in Davis or Woodland, because these TOD areas already were quite dense and the surrounding zones were also dense. For the CBD and non-CBD zones a density cap of around 8 households per acre and 10 retail and 30 non-retail employees per acre were used as guidelines in shifting the land use. The land use shift and TOD zone density Tables are shown in Appendix B.

No changes were made in the special generators and gateway trips that are included in the land use data.

FINDINGS AND DISCUSSION

A. The Substantive Automation Results :

*I. Comparison **of** HOV Automation Alternatives*

For this analysis, we will only examine the fully iterated model runs (Tables 12.1 and 12.3). VMT increased from 5 1.09 million miles (non-automated HOV lanes) to 52.5 1 million miles for the 60 mph with 1 second headways alternative and to 52.81 million miles for the 80 mph with 0.5 second headways alternative (Table 12.1). The increase in trip lengths due to higher speeds must have exceeded the reduction in trips due to increasing vehicle occupancy. Trip length increased with increasing automated speed. Similarly the total vehicle hours increased slightly upon automation to 60 mph with 1 second headways but decreased slightly when the automation speed was increased to 80 mph and headways decreased to 0.5 second.

The biggest change in automating the HOV lanes is the increase in the total vehicle hours of delay (VHD) for all facilities. The total VHD increases from 320,300 hours for the non-automated HOV to 356,300 hours for the 60 mph 1 second headways automated HOV alternative and to 371,100 hours for the 80 mph 0.5 second headways automated HOV alternative. These increases are mainly due to increased shared vehicle trips (SR2 and SR3+). Note that increased trips for home based work shared rides for the 60 mph alternative corresponds to a decrease of shared vehicle trips for other trip purposes. Percentage delay reduction from the automated HOV alternatives are ranked 5th and 6th among all the alternatives that were studied, but the non-automated HOV alternative performs better (ranked 2nd).

Lane miles of congestion (LOS E and F) on freeways increase under automation for the 60 mph alternative and the 80 mph alternative. This was due to the increased VMT, speeds, trip lengths and total vehicle hours for the 60 mph alternative and the increased VMT for the 80 mph alternative as compared to the non-automated HOV alternative (Table 12.1). For the HOV lanes, the Lane Miles of Congestion decrease with automation since we are increasing the capacity of the lanes to 3600 v/h/l for the 60 mph alternative and 7200 v/h/l for the 80 mph alternative.

*2. Comparison **of** Freeway Automation Alternatives*

Total delay is reduced by all of the automation alternatives except for the Automated HOV 60 mph with 1 second headway (HOV1) and automated HOV 80 mph with 0.5 second (HOV2) headway in which both have slight increases in VHD, 1.83% and 6.06% respectively (Table 12. 1), when compared to the 2010 No-Build alternative. Partial automation where only LOS E and F links are automated has the lowest total delay, compared to the 2010 No Build alternative. Automating (mixed flow) freeway links, however, increases VMT compared to the year 2010 No-Build alternative (49.58 million miles) for all of these automation alternatives (Table 12.1). The increase is by 6.9% for the Partial Automation (60 mph) alternative (52.68 million miles), 4.73 % for the Full Automation (60 mph) alternative (5 1.61 million miles) and by 5.56% for the Full Automation (80 mph) alternative (52.02 million miles). This is true since increased speed increases trip lengths in general.

Partial Automation produces greater VMT than the fully automated alternatives, however. The lower VMT for the Full Automation alternatives is the result of the increased number of arterial links and ramps which experience increased congestion (ramps are included within the freeway class). Both VHD and lane-miles of congestion increase from alternative 1 to alternative 2 and again to alternative 3, reflecting this congestion, even though alternatives 1 and 2 contain widened ramps and widened nearby arterials. Automating all of the freeway lanes overloads the ramps and arterials and average trip lengths and speeds go down.

3. Comparison with Previous Studies

We cannot compare our results with those of the SCAG (1992) study, because we have not produced emissions projections yet. That study did not project daily travel and so we cannot compare our VMT, trips, and VHD populations. Our results were broadly compatible with those of the earlier research on the effects of added urban highway capacity : travel moved off of arterials and onto freeways, travelers switched from transit to auto, and longer trips resulted. We could not simulate the effects on departure times, auto ownership, person-trip generation, and new land developments. The SACOG model will include departure times and auto ownership, beginning in the Summer of 1993.

B. The Methodological Results Concerning Automation :

The two protocols used were the ‘feedback to mode choice only’ (partial feedback) runs (Tables 12.2 and 12.4) and the ‘feedback to mode choice and trip distribution’ (full feedback) runs (Tables 12.1 and 12.3). The VMT for each alternative was reduced considerably in the full feedback runs, but by varying degrees for each of the alternatives studied. This is primarily the result of the varying effect of congested speeds on the systemwide performance of the different alternatives in the Trip Distribution step. Since the first run is based on the posted speeds of the network, the VMT generated from this run had to be the highest with outputs (VMT, VHT etc.) from subsequent results behaving in a decreasing sinusoidal manner (similar to a spring dampening curve). All other parameters behaved in a similar (well-behaved) fashion, decreasing sinusoidally and converging toward single values after several iterations.

1. Comparison of HOV Automation Alternatives Between the Two Protocols

In the partial feedback protocol (Tables 12.2 and 12.4) we see that the VMT does not increase in the automated HOV alternatives compared to the standard HOV alternative. This protocol does not take into account the congested speed of the network in the trip distribution step and so does not show the effect of speeds on trip lengths. The Automated HOV lane alternatives performed better with regards to delay (Better VHD ranking) than the non-automated alternative.

When congested speeds are used (Tables 12.1 and 12.3) in the full feedback process, the VMT increases. This is true for the VHT, total delay and total lane miles of congestion also and hence full feedback process shows a behavioral difference compared to the partial feedback process. The full feedback reduced the VMT by between 5 to 8% and reduced delay considerably by 24 to 39% for all three HOV alternatives. Full feedback thus altered the VHD rank order, with the non-automated HOV performing better than the automated HOV lane alternatives this time. The average trip length increases for the full feedback but decreases for the partial feedback process.

The linked transit trips whereas for both the feedback protocols, perform similarly. The linked transit trips decreases with automation of the HOV lanes. The total vehicle trips whereas shows slight variation with an increase in vehicle trips for the HOV2 Automation alternative compared to the HOV1 alternative for the full feedback but not in the partial feedback process.

2. *Comparison of Freeway Automation Alternatives Between the Two Protocols*

The full feedback process decreased the VMT by 11.3% for the Partial Automation alternative, 12.69% for the Full Automation (60 mph) alternative, and by 12.2% for the Full Automation (80 mph) alternative, when comparing with the partial feedback protocol. The average trip length decreases in the full feedback protocol due to the lower (congested) speeds. The average trip length decreases by 11.5% for Partial Automation, 12.75 % for the Full Automation (60 mph) alternative and 12.17% for the Full Automation (80 mph) alternative, paralelling the decreases in VMT. Feedback of congested travel impedances to trip distribution and mode choice has a greater effect on the vehicle hours delay. VHD decreases by about 39.3% for Partial Automation, 46.2% for the Full Automation (60 mph) and 45.2% for the Full Automation (80 mph) alternative.

The full feedback process increases the transit walk access trips (see Table 12.9) for the full automation and 2010 No-Build alternatives by about 7 to 9%. But this is not true for the Partial Automation alternative, where there are significant decreases in the number of transit walk access trips. The freeway links that are automated in the partially automated alternative are limited. This results in higher speeds (this alternative has the highest average network speed), thus increasing the mode choice split toward non-transit modes. Similarly the transit drive access trips increase for the full automation and NO-Build alternatives. For the Partial Automation alternative there is a 3-fold decrease, due to the increased speeds.

C. The Substantive Travel Demand Management Results :

In this section, we only discuss the fully iterated runs (Tables 12.5 and 12.7). The TOD scenario results in the lowest VMT (Table 12.5). This is mainly due to the largest transit ridership (TWA and TDA rows, in Table 12.5). The TOD alternative also has the shortest trip length (ATL row, Table 12.5), also due mainly to the high transit ridership. The TOD scenario produced more VHD then did the Pricing one, because under Pricing peak-period road charges reduced peak-period flows, by greatly increasing HOV2+ and 3 + for all trip purposes (HOV trips only show up directly for the work trips in Table 12.5, but all HOV trips are included in the All Linked Transit Trips row below). Non-work-trip transit ridership is overprojected by the model, because it factors these transit shares from the work trip share, and the other trips are not so predominantly during the peak-period and so are not affected as much by the peak-period charge. AVO is higher in the pricing scenario, for the same reason.

The LRT scenario has a lower VMT than does Pricing, because pricing reduced peak-period trips and congestion and so auto travel is faster and therefore these trips are longer. This illustrates the fact that some pricing measures will reduce VMT, while others will reduce congestion and increase VMT. Most agencies think that they can reduce congestion and VMT at the same time. This will be difficult or impossible, as our discussions of pricing and HOV lanes illustrate.

The No-Build scenario has lower VMT than does the HOV scenario, a counter-intuitive finding for most readers. This is because the HOV alternative adds the HOV lanes to most of the inner freeways, which takes many cars off of the mixed-flow lanes, thereby reducing congestion and increasing speeds and trip lengths. Emissions may be reduced by the HOV scenario, however, if the decrease in VMT below 10 mph (where emissions per mile rise rapidly) can offset the small increase in VMT at higher speeds.

On the other hand, the Pricing scenario may have the lowest emissions, because it has the lowest VHD and therefore probably the lowest VMT below 10 mph, and also has a very low VMT, lower than that for HOV. We cannot tell until we run the emissions model, but it appears that new HOV lanes may not reduce emissions, compared to Pricing and TODs, and even compared to No-Build. The Sacramento County general plan using TODs less dense than ours looks like it probably will reduce VMT and emissions and fuel use and CO2 emissions.

To account for the slight differences across the alternatives in person-trips, which is due to rounding in the many calculation steps, we factored the TOD VMT up to make account for its smaller total person-trips (X 1.00404). The resultant corrected VMT, 47.00, does not change our findings.

An extra alternative that combines the pricing and land use policies was also run. The combined policies resulted in a projected VMT (full Feedback) of 45.66 million miles and in VHT of 1,106,000 hours, the lowest values of any alternative (Table 12.5). This means that this is probably the least-cost scenario, since travel costs are for time and distance. LRT with Pricing has less total VHD (273,500) than Pricing plus Land Use (301,000), because the TODs encourage transit ridership more and HOV use less than the LRT with Pricing scenario.

We also need to ask if the models used are capable of fully simulating the effects of the TDM policies tested. The effects of fuel taxes and parking charges are well-represented in terms of mode choice. Such increases in cost would also affect auto ownership by households and this behavior is not modeled. Large price increases would also affect trip lengths by shortening them somewhat, but this behavior is also not simulated. These model weaknesses will produce projections that underestimate the reductions in VMT due to fuel and parking (base) pricing. Peak-hour pricing is very imperfectly represented, because the SACOG model is a daily travel model with factoring used for peak-hour estimation. We changed per-mile tolls for home-based work trips and in the peak-hour runs this moves travelers into HOVs. This probably represents the effects of the tolls fairly well. However, the non-work trip mode shares are factored off the work trip mode shares and so the model over-represents total HOV and transit trips. It is unclear if VMT is overprojected or under-projected if all three pricing policies are simulated together.

The model steps have no land use variables in them and so land use density and mix affects only trip distribution, not auto ownership or trip generation. Mode choice is affected by the increase in households within short walk access times to rail stations, but not by other land use variables, such as mix. The VMT reductions from the land use policies are underprojected.

Comparison with Previous Studies

Our results are broadly compatible with those of the studies reviewed above. Our Pricing scenario reduced VMT less than did similar packages of policies evaluated in the Bay Area and in Southern California (4 % versus about 10%). Reasons may include: we modeled a $2/gal. fuel tax as only $0.40, to account for the long-run elasticity of demand for miles travelled (people buy higher-mpg autos, and so the price-elasticity of demand is -0.3); our region has poor transit service compared to the Bay Area and parts of Southern California; our freeways are uncongested compared to the other two areas; and our model is daily with factoring for the peak hour, rather than separately calibrated for peak and non-peak, as is the case in the other two regions.

Our land use policies had an effect roughly similar to those reviewed above. We projected very optimistic levels of density and mix in our TODs, levels that would not easily be achieved. Our models do not include an auto ownership step, and so the effects of land use on trip generation are not included. Also, mode choice is not affected by land use density or mix, and so the model is insensitive to land use policies. The new models under development now will probably project larger reductions in VMT from our land use policies.

D. The Methodological Results Concemine TDMs:

Here, we compare the full feedback runs (Tables 12.5 and 12.7) with the partial feedback runs (Tables 12.6 and 12.8). Full feedback greatly reduces all of the VMT and VHT projections, due to the effects of road congestion being felt by all of the model steps (Table 12.5). The VHD and Lane-miles of Congestion projections are reduced by even greater percentages, as expected, since congestion increases nonlinearly with volumes as link volumes approach link capacities.

The TOD and No-Build alternatives have the greatest reductions in VHD, compared with the free-flow runs (Table 12.5). This is because the HOV alternative is adding capacity as is the Pricing alternative by reducing peak travel and so they have less congestion. It is unclear why the LRT alternative does not have a higher reduction in VHD, compared to the free-flow run. Perhaps it is because transit pulls autos off of roadways during peak periods, thereby reducing congestion.

Full iteration changes the rankings for some of the scenarios. LRT has lower VMT than does Pricing under full iteration (Table 12.5) and the reverse is true under free-flow (Table 12.6). This is because Pricing reduces congestion more, due to the peak-period tolls, which increase HOV use on the existing lanes. The reduced congestion results in longer trip distances, because travellers are on fixed time budgets in this and most models. That is, the travel distances are fitted to the base year trip time-distance distribution curves for each trip purpose.

Full feedback is necessary to show the effects of different levels of congestion correctly. HOV lanes compete with transit directly for riders and also reduce congestion, both of which effects increase VMT. The increased VMT may increase emissions, as noted above.

Another interesting finding is that full feedback reduced the percentage of transit trips for all of the scenarios (Table 12.7 versus Table 12.8), due to congestion reducing travel speeds and distances and direct (distance-based) costs, which results in more auto use, compared with transit. The federal transit agency (UMTA, now FTA) has prohibited the full feedback method in the past. It appears that they may wish to require this method, since it seems to more accurately represent future ridership by reducing the overprojection so common among MPOs.

Our land use scenario showed that the new employment and housing to occur in the next 20 years are both very scattered around, far from the planned light rail stations, and so will not help transit to be cost effective and to reduce travel and emissions. We moved about 75% of new residential units and 75 % of new employment to the TOD's. Our densities are higher than the City and County planners told us were "feasible". We think that they will be feasible in 20 years, however. The MPO (SACOG) and its local government members need to continue their consideration of land use planning to reinforce the transit system and study stronger TOD scenarios. Sacramento County has adopted a fairly good plan for TODs, but it is cautious.

Pricing policies that include congestion pricing reduce peak-hour auto volumes and increase speeds and VMT slightly, compared to just doing LRT. Whereas the Pricing scenario does have the lowest VHD and Lane-Miles of Congestion, it most likely does not have the lowest emissions or cost. From this we conclude that pricing to relieve congestion will have different effects than pricing to reduce auto travel (fuel taxes, parking pricing). This shows that congestion relief and travel reduction may not be compatible, as agencies hope they are. The good performance of the No-Build alternative compared to building HOV lanes and to expanding LRT, shows that adding road capacity increases VMT and probably emissions. Many economists recommend not adding freeway capacity in most urban regions in the U.S., arguing that congestion is self limiting as people move closer to their jobs.

TABLE 12.1

Automation Protocols : Feedback of Congested Travel Times To Trip Distribution and Mode Choice

NETWORK ATTRIBUTES	1989 Base	2010 NO-BUILD	HOV	HOV1 60mph	HOV2 80mph	L.R.T ALT 8	AUTO1 Partial	AUTO2 60mph	AUTO3 80mph
V M T (in millions)	30.4	49.28	51.09	52.51	52.81	48.97	52.68	51.61	52.02
% Below Free Flow Run	4.8	11.9	8.36	5.44	4.85	11.8	11.3	12.69	12.2
% Diff over No-Build			+3.67	+6.55	+7.16	0.63	+6.90	+4.73	+5.56
V.M.T Ranking			2	5	7	1	6	3	4
Tot Veh Hours(thousands)	734	1198	1225	1260	1256	1188	1200	1227	1192
Veh Hours Delay(thousands)									
On Freeways	16.5	121	103.7	108.4	111.3	117	87.02	98.5	102
On HOV Lanes	--	0.4	5.3	1.9	10.8	45	--	--	--
On Others	56.4	228.5	211.3	246	249	225	193	222	222
Total VHD	72.9	349.9	320.3	356.3	371.1	387	280	321	324
% Below Free Flow *Run*	43	49.4	38.7	25.68	23.7	40.2	39.3	46.2	45.2
Avrg Network Speed(mph)	41.41	41.15	41.71	41.68	42.06	41.22	43.85	42.07	43.65
Lane Miles of Cong.	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F
on Freeways	264	400.9	332.8	391.5	409	367	216	267	262
On HOV Lanes	0	0	15.5	2	0	0	0	0	0
On Arterials	328	373	329.2	378	387	352	276	330	318
Total L.M.C	592	773.9	677.5	771.5	796	719	492	597	580
Average Trip Length	8.94	9.23	9.63	9.8	9.85	9.22	9.85	9.66	9.74
Avrg Veh. Occupancy	1.288	1.289	1.301	1.294	1.295	1.289	1.289	1.296	1.289
VHD Reduction (% Below 2010)	--	--	8.5	+1.83	+6.06	+10.6	19.98	8.23	7.4
VHD Ranking			2	5	6	7	1	3	4

Notes:

1. HOV1 -- In This Alternative HOV lanes are automated to 60 mph and 1 sec Headway
2. HOV2 -- In This Alternative HOV lanes are automated to 80 mph and 0.5 sec Headway
3. AUTO1 consists of partially automated freeway links (of LOS E/F) to 60 mph 1 sec Headway
4. AUTO2 consists of fully automated freeway links to 60 mph 1 sec Headway
5. AUTO3 consists of fully automated freeway links to 80 mph 0.5 sec Headway

TABLE 12.2

Automation Protocols : Feedback of Congested Travel Time To Mode Choice

NETWORK Al-TRIBUTES	1989 Base	2010 NO-BUILD	HOV	HOV1 60mph	HOV2 80mph	L.R.T ALT 8	AUTO1 Partial	AUTO2 60mph	AUTO3 80mph
V M T (in millions)	31.92	55.93	55.75	55.53	55.5	55.53	59.42	59.11	59.26
% Over 2010 No-Build			-0.32	-0.72	-0.77	-0.72	+6.24	+5.69	+5.95
V.M.T Ranking			3	2	1	2	6	4	5
Tot. Veh. Hours (thousands)	77	1369	1349	1340	1327	1358	1343	1407	1351
Veh. Hours Delay (thousands)									
On Freeways	23.3	250	155	138	137	230	148	195	203
On HOV Lanes	0	0	11.7	3	11.8	0	0	0	0
On Others	104.83	442	356	338.4	337	418	313	402	388
Total VHD	128.13	692	522.7	479.4	485.8	648	461	597	591
Avrg Network Speed(mph)	41.37	40.86	41.34	41.44	41.81	40.89	44.24	42.03	43.85
Lane Miles of Cong.	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F
On Freeways	496	690	557	519	512	667	348	496	475
On HOV Lanes	0	0	37	4	0	0	0	0	0
On Arterials	631	759	581	543	538	719	480	631	611
Total L.M.C	1127	1449	1175	1066	1050	1386	828	1127	1086
Average Trip Length	9.39	10.47	10.49	10.48	10.48	10.47	11.13	11.07	11.09
Avrg Veh. Occupancy	1.288	1.289	1.304	1.304	1.296	1.289	1.289	1.29	1.289
VHD Reduction (% over 2010 No Build)	--	--	24.47	30.72	29.80	6.36	33.38	13.73	14.60
VHD Ranking			4	2	3	7	1	6	5

Notes:

1. HOV1 -- In This Alternative HOV lanes are automated to 60 mph and 1 sec Headway
2. HOV2 -- In This Alternative HOV lanes are automated to 80 mph and 0.5 sec Headway
3. AUTO1 consists of partially automated freeway links (of LOS E/F) to 60 mph 1 sec Headway
4. AUTO2 consists of fully automated freeway links to 60 mph 1 sec Headway
5. AUTO3 consists of fully automated freeway links to 80 mph 0.5 sec Headway

TABLE 12.3

AUTOMATION PROTOCOLS: FEEDBACK TO TRIP DISTRIBUTION AND MODE CHOICE

	1989 Base	2010 NoBuild	HOV	HOV1 60mph	HOV2 80mph	LRT Alt 8	AUTO1 Partial	AUTO2 60mph	AUTO3 80mph
VMT	30403232	49284839	51094166	52514152	52805696	48934960	52677175	51608030	52016755
TOT HOURS	734132	1197552	1225260	1260019	1255724	1186631	1200832	1226537	1191397
Daily Person Trips By Purpose and Mode:									
HBW-TWA	21662	23559	31730	31742	32188	36690	19842	23020	22999
HBW-TDA	9475	13989	32250	33251	33662	37371	11971	13931	13719
HBW-DA	781661	1274850	1246332	1232347	1225754	1258778	1277041	1273867	1274678
HBW-SR2	128821	214326	227538	238291	240222	209051	216934	215541	215032
HBW-SR3+	26422	42480	44626	46862	47274	40500	43432	42842	42762
HBO-TWA	21407	24342	30248	29912	31236	29216	18495	23580	23442
HBO-TDA	2167	3071	8907	9362	9461	10482	2399	3103	3075
HBO-AA	2434314	3892669	3880927	3880810	3880572	3880385	3899188	3893399	3893566
NHB-TWA	6845	8694	10563	10444	10652	9016	6221	8435	8371
NHB-TDA	985	1256	3612	3768	3961	3782	999	1304	1303
NHB-AA	1008290	1456689	1452465	1452426	1454238	1453174	1459419	1456899	1456964
Tot. Pers. Trips	4442048	6955924	6969198	6969215	6969220	6968445	6955939	6955921	6955911
Linked Transit Trips	62540	74910	117310	118479	121160	126557	59926	73373	72908
% Linked Transit Trips	1.41	1.08	1.68	1.70	1.74	1.82	0.86	1.05	1.05
Daily Vehicle Trips:									
Drive Alone	2558702	4011519	3974983	3960916	3960342	3987683	4018428	4011004	4011929
2+ HOV	841468	1328428	1332052	1338033	1338814	1321592	1332060	1329356	1329128
Tot. Veh. Trips	3400170	5339947	5307035	5298949	5299156	5309275	5350488	5340361	5341058
A.T.L	8.942	9.229	9.628	9.910	9.965	9.217	9.845	9.664	9.739
A.V.O	1.288	1.289	1.291	1.293	1.292	1.289	1.289	1.289	1.289

A.T.L - Average Trips Length

A.V.O - Average Vehicle Occupancy

HBW-Home Based Work, TWA-Transit Walk Access, TDA-Transit Drive Access

SR2-Shared Ride 2 Persons, SR3+-Shared Ride 3+ Persons

HBO-Home Based Other, AA-All Auto Person Trips

NHB-Non Home Based

TABLE 12.4

AUTOMATION PROTOCOLS: FEEDBACK TO MODE CHOICE

	1989 Base	2010 NoBuild	HOV	HOV1 60mph	HOV2 80mph	LRT Alt 8	AUTO1 Partial	AUTO2 60mph	AUTO3 80mph
VMT	31923938	55925736	55745401	55528900	55502196	55538030	59420980	59114431	59255664
TOT HOURS	771665	1368678	1348455	1339879	1327224	1358092	1343222	1406523	1351220
Daily Person Trips By Purpose and Mode:									
HBW-TWA	21307	21857	30622	31179	31411	37605	21408	21151	21340
HBW-TDA	9697	14892	32211	33339	33567	40026	13697	14012	13451
HBW-DA	780734	1269363	1241617	1225135	1222633	1250114	1269279	1268028	1269834
HBW-SR2	129636	219139	232162	244487	246180	212925	220400	221447	220188
HBW-SR3+	26653	43994	45883	48351	48712	41705	44425	44626	44414
HBO-TWA	21010	22672	29757	29709	30013	29450	21917	21767	21787
HBO-TDA	2322	3402	9216	9548	9546	11292	3325	3296	3117
HBO-AA	2434555	3894008	3881109	3880825	3880523	3879340	3894840	3895020	3895179
NHB-TWA	6717	8129	10214	10223	10314	9171	7797	7812	7765
NHB-TDA	1065	1503	3788	3920	3964	4776	1405	1451	1436
NHB-AA	1008337	1457006	1452637	1452495	1452362	1452691	1457437	1457375	1457438
Tot. Pers. Trips	4442033	6955965	6969216	6969211	6969225	6969095	6955930	6955985	6955949
Linked Transit Trips	62118	72455	115808	117918	118815	132320	69549	69489	68896
% Linked Transit Trips	1.40	1.04	1.66	1.69	1.70	1.90	1.00	1.00	0.99
Daily Vehicle Trips:									
DA	2557903	4006831	3970472	3953767	3951047	3978225	4007403	4006200	4008115
2+ HOV	842011	1331657	1334797	1341572	1342422	1323542	1332700	1333294	1332652
Tot. Veh. Trips	3399914	5338488	5305269	5295339	5293469	5301767	5340103	5339494	5340767
A.T.L	9.39	10.48	10.51	10.49	10.49	10.48	11.13	11.07	11.09
A.V.O	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29

A.T.L - Average Trip Length
A.V.O - Average Vehicle Occupancy

HBW-Home Based Work, TDW-Transit Walk Access, TDA-Transit Drive Access
SR2-Shared Ride 2 Persons, SR3+-Shared Ride 3+ Persons
HBO-Home Based Other, AA-All Auto Person Trips
NHB-Non Home Based
DA-Drive Alone

TABLE 12.5

Transit Oriented Development & Pricing:FEEDBACK TO TRIP DISTRIBUTION AND MODE CHOICE

NETWORK ATTRIBUTES	1989 Base	2010 NO-BUILD	HOV	L.R.T ALT 8	L.R.T WITH PRICING	T.O.D	T.O.D WITH PRICING
V M T (in millions)	30.4	49.28	51.09	48.97	49.25	46.81	45.66
% Below Free Flow Run	4.8	11.9	8.36	11.8	8.36	12.34	11.7
% Below 2010 No-Build			+3.6	-0.63	-0.06	-5.01	-7.35
V M T Ranking			5	3	4	2	1
Total Veh. Hours(Thousands)	734	1198	1225	1188	1178	1136	1106
Veh. Hours Delay(Thousands)							
On Freeways	16.5	121	103.7	117	83	120	106
On HOV Lanes	0	0.4	5.3	45	8.5	0	0.1
On Others	56.4	228.5	211.3	225	182	214	195
Total VHD	72.9	349.9	320.3	387	273.5	334	301.1
%Tot. Below Free Flow Run	4 3	-49.4	-38.7	-40.2	-37.45	-48.26	-48.52
Avrg Network Speed(mph)	41.41	41.15	41.71	41.22	41.8	41.22	41.3
Lane Miles of Cong.	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F
on Freeways	264	400.9	332.8	367	251	286	271
On HOV Lanes	0	0	15.5	0	22	0	2
On Arterials	328	373	329.2	352	269	326	301
Total L.M.C	592	773.9	677.5	719	542	612	574
Average Trip Length	8.94	9.23	9.63	9.22	9.52	8.89	9.52
Avrg Veh. Occupancy	1.288	1.289	1.301	1.289	1.33	1.29	1.33
VHD Reduction (% Below 2010)	--	--	-8.46	t10.6	-21.8	-4.54	-13.95
VHD Ranking			3	5	1	4	2

TABLE 12.6

Transit Oriented Development and Pricing: FEEDBACK TO MODE CHOICE

NETWORK A-I-TRIBUTES	1989 Base	2010 NO-BUILD	HOV	L.R.T ALT 8	L.R.T PRICING	T.O.D	T.O.D PRICING
V M T (in millions)	31.92	55.93	55.75	55.53	53.74	53.4	51.71
% below 2010 No-Build			-0.32	-0.7	-3.92	-4.52	-7.55
V M T Ranking			5	4	3	2	1
Total Veh. Hours (in thousands)	771	1369	1349	1358	1294	1304	1261
Veh. Hours Delay (In Thousan							
On Freeways	23.3	250	155	230	133	253	227
On HOV Lanes		0	11.7	0	0.22	0.58	1
On Others	104.83	442	356	418	304	392	356
Total VHD	128.13	692	522.7	648	437.22	645.58	584
Avrg Network Speed(mph)	41.37	40.86	41.34	40.89	41.52	40.94	41.00
Lane Miles of Cong.	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F
on Freeways	496	690	557	667	465	582	530
On HOV Lanes	0	0	37	0	49	0	0
On Arterials	631	759	581	719	478	600	567
Total L.M.C	1127	1449	1175	1386	992	1182	1097
Average Trip Length	9.39	10.47	10.49	10.47	10.38	10.17	10.07
Avrg Veh. Occupancy	1.288	1.289	1.304	1.289	1.33	1.29	1.33
VHD Reduction (% over 2010 No Build)	--	--	-24.5	-6.4	-36.8	-6.7	-15.6
VHD Ranking			2	5	1	4	3

TABLE 12.7

Transit Oriented Developments & Pricing: FEEDBACK TO TRIP DISTRIBUTION AND MODE CHOICE

	1989 Base	2010 NoBuild	HOV	LRT Alt 8	LRT WITH PRICING	T.O.D	T.O.D WITH PRICING
VMT	30403232	49284839	51094166	48934960	49246709	46806345	45662453
TOT HOURS	734132	1197552	1225260	1186631	1178368	1135705	1105876
Daily Person Trips By Purpose and Mode:							
HBW-TWA	21662	23559	31730	36690	24489	48440	29746
HBW-TDA	9475	13989	32250	37371	28808	36201	26986
HBW-DA	781661	1274850	1246332	1258778	938668	1187737	887093
HBW-SR2	128821	214326	227538	209051	558906	197640	536630
HBW-SR3+	26422	42480	44626	40500	29685	39861	26669
HBO-TWA	21407	24342	30248	29216	21572	38013	26736
HBO-TDA	2167	3071	8907	10482	8046	11376	8922
HBO-AA	2434314	3892669	3880927	3880385	3890464	3839437	3853169
NHB-TWA	6845	8694	10563	9016	6303	12016	8231
NHB-TDA	985	1256	3612	3782	3069	5104	3486
NHB-AA	1008290	1456689	1452465	1453174	1457267	1524216	1529618
Total Person Trips	4442048	6955924	6969198	6968445	6967278	6940040	6937286
Linked Transit Trips	62540	74910	117310	126557	92287	151149	104107
% Linked Transit Trips	1.41	1.08	1.68	1.82	1.32	2.18	1.50
Daily Vehicle Trips:							
Drive Alone	2558702	4011519	3974983	3987683	3677069	3947978	3657035
2+ HOV	841468	1328428	1332052	1321592	1496584	1315313	1485320
Total Vehicle Trips	3400170	5339947	5307035	5309275	5173653	5263291	5142355
A.T.L	8.94	9.23	9.63	9.22	9.52	8.89	8.88
A.V.O	1.29	1.29	1.29	1.29	1.33	1.29	1.33

A.T.L - Average Trips Length

A.V.O - Average Vehicle Occupancy

HBW-Home Based Work, TWA-Transit Walk Access, TDA-Transit Drive Access

SR2-Shared Ride 2 Persons, SR3+-Shared Ride 3+ Persons

HBO-Home Based Other, AA-All Auto Person Trips

TABLE 12.8

Transit Oriented Developments & Pricing: FEEDBACK TO MODE CHOICE

	1989 Base	2010 NoBuild	HOV	LRT Alt 8	L.R.T WITH PRICING	T.O.D	T.O.D WITH PRICING
VMT	31923938	55925736	55745401	55538030	53735206	53400328	51714402
TOT HOURS	771665	1368678	1348455	1358092	1294216	1304369	1261340
Daily Person Trips By Purpose and Mode:							
HBW-TWA	21307	21857	30622	37605	24883	51144	31453
HBW-TDA	9697	14892	32211	40026	29958	37967	28634
HBW-DA	780734	1269363	1241617	1250114	932055	1178577	879302
HBW-SR2	129636	219139	232162	212925	555532	201328	540249
HBW-SR3+	26653	43994	45883	41705	28979	40864	27454
HBO-TWA	21010	22672	29757	29450	21461	40817	28846
HBO-TDA	2322	3402	9216	11292	7990	12774	9836
HBO-AA	2434555	3894008	3881109	3879340	3890631	3835235	3850144
NHB-TWA	6717	8129	10214	9171	6237	12989	8981
NHB-TDA	1065	1503	3788	4776	2990	5621	3862
NHB-AA	1008337	1457006	1452637	1452691	1457412	1522727	1528492
Total Person Trips	4411029	6919216	6919216	6969095	6958128	6940043	6937253
Linked Transit Trips	62118	72455	115808	132320	93519	161312	111612
% Linked Transit Trips	1.41	1.05	1.67	1.90	1.34	2.32	1.61
Daily Vehicle Trips:							
Drive Alone	2557903	4006831	3970472	3978225	3682066	3935952	3647154
2+ HOV	842011	1331657	1334797	1323542	1494768	1316165	1486432
Total Vehicle Trips	3399914	5338488	5305269	5301767	5176834	5252117	5133586
A.T.L	9.39	10.48	10.51	10.48	10.38	10.17	10.07
A.V.O	1.29	1.29	1.29	1.29	1.33	1.29	1.33

A.T.L - Average Trip Length

A.V.O - Average Vehicle Occupancy

HBW-Home Based Work, TDW-Transit Walk Access, TDA-Transit Drive Access

SR2-Shared Ride 2 Persons, SR3+-Shared Ride 3+ Persons

HBO-Home Based Other, AA-All Auto Person Trips

NHB-Non Home Based

TABLE 12.9

Percent Difference Between Feedback Modeling Protocols of Person Trip and Vehicle Trips:

	Mode Choice Only				Trip Dist & Mode Ch.				Percent Difference			
	2010	AUTO 1	AUTO2	AUTO3	2010	AUTO1	AUTO2	AUTO3	2010	AUTO1	AUTO2	AUTO3
	NO BUILD	Partial	60mph	80mph	NO BUILD	Partial	60mph	80mph	NO BUIL	Partial	60mph	80mph
VMT	55925736	59420980	59114431	59255664	49284839	52677175	51608030	52016755	-11.87	-11.35	-12.70	-12.22
TOT HOURS	1368678	1343222	1406523	1351220	1197552.2	1200832	1226537	1191397	-12.50	-10.60	-12.80	-11.83
Daily Person Tri												
HBW-TWA	21857	21408	21151	21340	23559	19842	23020	22999	7.79	-7.32	8.83	7.77
HBW-TDA	14892	13697	14012	13451	13989	11971	13931	13719	-6.07	-12.60	-0.58	1.99
HBW-DA	1269363	1269279	1268028	1269834	1274850	1277041	1273867	1274678	0.43	0.61	0.46	0.38
HBW-SR2	219139	220400	221447	220188	214326	216934	215541	215032	-2.20	-1.57	-2.67	-2.34
HBW-SR3+	43994	44425	44626	44414	42480	43432	42842	42762	-3.44	-2.24	-4.00	-3.72
HBO-TWA	22672	21917	21767	21787	24342	18495	23580	23442	7.37	-15.62	8.33	7.60
HBO-TDA	3402	3325	3296	3117	3071	2399	3103	3075	-9.74	-27.84	-5.85	-1.36
HBO-AA	3894008	3894840	3895020	3895179	3892669	3899188	3893399	3893566	-0.03	0.11	-0.04	-0.04
NHB-I-WA	8129	7797	7812	7765	8694	6221	8435	8371	6.94	-20.22	7.97	7.80
NHB-TDA	1503	1405	1451	1436	1256	999	1304	1303	-16.42	-28.87	-10.11	-9.25
NHB-AA	1457006	1457437	1457375	1457438	1456689	1459419	1456899	1456964	-0.02	0.14	-0.03	-0.03
Total Person Trips	6919216	6920825	6955985	6921158	6955923.8	6955939	6955921	6955911	0.53	0.51	-0.00	0.50
Daily Vehicle Tri												
Drive Alone	4006831	4007403	4006200	4008115	4011519.2	4018428	4011004	4011929	0.12	0.28	0.12	0.10
2+ HOV	1331657	1332700	1333294	1332652	1328428.2	1332060	1329356	1329128	-0.24	-0.05	-0.30	-0.26
Total Vehicle Trips	5338488	5340103	5339494	5340767	5339947.3	5350488	5340361	5341058	0.03	0.19	0.02	0.01
Lane Miles of Cc	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F				
on Freeways	690	348	496	475	382	216	267	262	-44.64	-37.93	-46.17	-44.84
On HOV Lanes	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00
On Arterials	759	480	631	611	434	276	330	318	-42.82	-42.50	-47.70	-47.95
A.T.L	10.476	11.127	11.071	11.095	9.229	9.845	9.664	9.739	-11.90	-11.52	-12.71	-12.22
A.V.O	1.289	1.290	1.290	1.290	1.289	1.289	1.289	1.289	-0.06	-0.05	-0.07	-0.06

A.T.L - Average Trips Length
A.V.O - Average Vehicle Occupancy
HBW-Home Based Work, TWA-Transit Walk Access, TDA-Transit Drive Access
SR2-Shared Ride 2 Persons, SR3+-Shared Ride 3+ Persons
HBO-Home Based Other, AA-All Auto Person Trips
NHB-Non Home Based

TABLE 12.10

Percent Difference Between Feedback Modeling Protocols of Person Trip and Vehicle Trips:

	Mode Choice Only				Trip Dist & Mode Ch.				Percent Difference			
	2010 NO BUILD	HOV	HOV 60mph	HOV 80mph	2010 NO BUILD	HOV	HOV 60mph	HOV 80mph	2010 JO BUILD	HOV	HOV 60mph	HOV 80mph
VMT	55925736	55745401	55528900	55502196	49284839	51094166	52514152	52805696	-11.87	3689.09	3819.32	3878.66
TOT HOURS	1368678	1348455	1339879	1327224	1197552	1225260	1260019	1255724	-12.50	-9.14	-5.96	-5.39
Daily Person Tri												
HBW-TWA	21857	30622	31179	31411	23559	31730	31742	32188	7.79	3.62	1.81	2.47
HBW-TDA	14892	32211	33339	33567	13989	32250	33251	33662	-6.07	0.12	-0.26	0.28
HBW-DA	1269363	1241617	1225135	1222633	1274850	1246332	1232347	1225754	0.43	0.38	0.59	0.26
HBW-SR2	219139	232162	244487	246180	214326	227538	238291	240222	-2.20	-1.99	-2.53	-2.42
HBW-SR3+	43994	45883	48351	48712	42480	44626	46862	47274	-3.44	-2.74	-3.08	-2.95
HBO-I-WA	22672	29757	29709	30013	24342	30248	29912	31236	7.37	1.65	0.68	4.07
HBO-TDA	3402	9216	9548	9546	3071	8907	9362	9461	-9.74	-3.35	-1.95	-0.89
HBO-AA	3894008	3881109	3880825	3880523	3892669	3880927	3880810	3880572	-0.03	-0.00	-0.00	0.00
NHB-TWA	8129	10214	10223	10314	8694	10563	10444	10652	6.94	3.42	2.16	3.28
NHB-TDA	1503	3788	3920	3964	1256	3612	3768	3961	-16.42	-4.65	-3.88	-0.08
NHB-AA	1457006	1452637	1452495	1452362	1456689	1452465	1452426	1454238	-0.02	-0.01	-0.00	0.13
Total Person Trips	6955965	6969216	6969211	6969225	6955923.8	6969198	6969215	6969220	-0.00	-0.00	0.00	-0.00
Daily Vehicle Tri												
Drive Alone	4006831	3970472	3953767	3951047	4011519.2	3974983	3960916	3960342	0.12	0.11	0.18	0.24
2+ HOV	1331657	1334797	1341572	1342422	1328428.2	1332052	1338033	1338814	-0.24	-0.21	-0.26	-0.27
Total Vehicle Trips	5338488	5305269	5295339	5293469	5339947.3	5307035	5298949	5299156	0.03	0.03	0.07	0.11
Lane Miles of Cc	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F	LOS E/F				
on Freeways	690	557	519	512	382	333	392	409	-44.64	-40.22	-24.47	-20.12
On HOV Lanes	0	37	4	0	0	16	2	0	0.00	0.00	0.00	0.00
On Arterials	759	581	543	538	434	329	378	387	-42.82	-43.37	-30.39	-28.07
A.T.L	10.476	10.507554	10.486373	10.485033	9.229	9.628	9.910	9.965	-11.90	-8.37	-5.49	-4.96
A.V.O	1.289	1.2918116	1.2938346	1.2941249	1.289	1.291	1.293	1.292	-0.06	-0.06	-0.08	-0.14

A.T.L - Average ps Length

A.V.O - Average Vehicle Occupancy

HBW-Home Based Work, TWA-Transit Walk Access, TDA-Transit Drive Access

SR2-Shared Ride 2 Persons, SR3+-Shared Ride 3+ Persons

HBO-Home Based Other, AA-All Auto Person Trips

NHB-Non Home Based

CONCLUSIONS

Our substantive results show that it is difficult to reduce both congestion and travel. Partial automation has the lowest VHD, but a very high VMT. All the other automation scenarios have higher VMT than LRT, HOV, and No-Build. LRT is ineffective in reducing delay, but HOV is fairly effective (Table 12.1). All of the TDM alternatives have lower VMT than all of the automation alternatives (Tables 12.1 and 12.5). LRT plus pricing has the lowest VHD and a lower VMT than any automation scenario. Partial automation has the next lowest VHD, but a high VMT. Automating more lane-miles than are needed to achieve LOS E increases VMT enough to increase VHD above that for Partial Automation, even in the automated HOV scenarios. Capacity must be added in only the amounts needed or the increased trip lengths overload the system.

A. Automation Scenarios :

Increasing speeds by automating freeways results in an increase in VMT (Table 12.1). Increased speed with decreased congestion such as in the Partial Automation alternative results in a greater increase of VMT. This scenario also results in the longest average trip length. This is a good scenario for reducing delay and congestion but probably not for trying to improve air quality.

For the HOV alternatives, increasing capacity and speeds also results in an increased propensity for travel and in decreased delay, compared to the No-Build alternative. The decrease in delay due to automation is comparatively lower and thus performs worse than non-automation and also worse than the freeway full automation alternatives. But again these alternatives perform better than the LRT alternative as far as congestion and delay is concerned but not with respect to reduced travel. All of the automation scenarios would induce low-density land developments on the edges of the urban area and this would result in longer trips and more trips per household. The models do not capture this effect and so VMT for these scenarios would be higher.

B. Transportation Demand Management Scenarios :

Pricing measures (Table 12.5) including peak period pricing move trips from the drive alone mode to the 2+ vehicle mode and also remove ridership from transit and push them into the 2+ vehicle mode. This tells us that applying parking pricing, congestion pricing, and gas tax increase results in increased carp001 and vanpool use, but at the same time reduces transit use. Pricing effectively reduces roadway delay and increases auto trip lengths. The reduced delays could reduce emissions to a greater extent than emissions are increased due to the increased trip length that the pricing measure induces, especially if the delays being reduced are on arterials at very low speeds. The systems planning study HOV alternative had similar unexpected effects.

Land use intensification with pricing (Table 12.5) is shown to reduce VMT the most. The decrease in transit ridership due to pricing, compared to land use alone, could be offset by the increase due to the TODs. But, the linked transit trips account for only 1-2% of the total person-trips. We will investigate HOV plus pricing in the future, as well as scenarios with improved transit service. The models used are quite insensitive to land use variables and so the

VMT in these scenarios is very likely significantly lower than our projections.

C. Comparisons between the Automation and TDM Measures :

As far as delay is concerned, there are only small differences between the ranges of the TDM and the automation scenarios. LRT with pricing and partial automation provide the lowest total vehicle hours of delay (Tables 12.1, 12.5). The 2010 No-Build has a much higher VHD.

The land use intensification, pricing, land use plus pricing, and LRT alternatives reduce VMT the most. The partial automation alternative and LRT plus pricing alternatives reduce the lane miles of congestion and total vehicle hours of delay the most. We can see that reducing congestion and delay results in an increased propensity for travel (increased VMT and VHT) and only these scenarios provide small additions of capacity.

D. Methodological :

We can see that the non-work transit trips can be over-projected by this model, i.e. their share is dependent on the work trip share and so TDMs that affect peak-period travel also affect non-peak travel in the model. This practice assumes that travelers in the peak and non-peak periods behave similarly, which is not true. To get a true representation of travel behavior for the non-work trips, a separate mode choice model needs to be developed and all models calibrated for peak and non-peak periods. Overprojection of off-peak transit trips using the factoring method removes too many trips from the peak period and so peak-period congestion may be under represented.

We can see that the full feedback process has a significant effect on mode shares, VMT, VHT, and congestion. With current modeling practices, vehicle hours of delay are generally overprojected. This would have a great impact on how we interpret the environmental impacts of certain mitigation measures using regional models. Also, federal and state transit funding agencies may wish to require the use of full feedback modeling protocols. Likewise, the EPA and state air quality agencies may wish to require this method to more accurately project emissions in conformity analyses.

FURTHER WORK

Related to the 1991-92 Work :

With the first quarter of our 1992-93 funding, we will complete running the scenarios, including the Take-a-Lane HOV, HOV plus Pricing, Take-a-Lane HOV plus Pricing, and Freeway Automation plus Pricing. We have acquired the ARB BURDEN model set up for PCs and will use the new EMFAC7E emissions factors. Our model runs include speeds over 55mph (up to over 70mph) and so we will be able to test the tradeoff between reducing congested speeds under 10 mph, which reduces emissions per mile greatly, and increasing travel off-peak over 50 mph, where emissions per mile also rise strongly.

The Funded 1992-93 Research :

We will re-run all of the scenarios on the new SACOG model set, which will be operational in July, 1993. This model will be much better at simulating the effects of congestion, because it will have peak and nonpeak models and will have full feedback of assigned speeds built into the model job codes. The model will also have post-processing of link speeds, so speeds should be more accurate. All link capacities are also being carefully reevaluated. We will use emissions correction factors for smooth (automated) traffic flows, being developed by Guensler and Sperling at UC Davis. This correction will help us to see if automation can reduce emissions from less acceleration and deceleration and overcome the extra emissions due to higher VMT and speeds.

We will estimate a logit mode choice model for nonwork trips, if the agency does not do this. This model will be used by us to project traveller costs and benefits, to use in our evaluations of automation. Better automation scenarios will be identified, such as with flyover ramps to urban centers next to freeways. Such an evaluation may show that automation save enough time costs for nonautomated travellers to allow subsidies to the purchasers of automation equipment.

Our Proposed 1993-94 Research :

We propose to: 1. evaluate automated, guided passenger transportation systems, including mechanically and electronically guided buses, Automated Guideway Transit, Personal Rapid Transit, and light rail vehicles, 2. identify the operating characteristics of these vehicles and of demand-responsive feeder vehicles (taxi, van, jitney, paratransit), 3. simulate the effects of these technologies with a state-of-the-art set of regional travel demand and emissions models for the standard 20-year period and also in 50-year sketch evaluations, and 4. compare these automated transit scenarios with other policies intended to reduce emissions and congestion, such as auto pricing. Our project covers parts of all three research program areas and places them into a real setting.

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APPENDIX A

DESCRIPTION OF SYSTEM ALTERNATIVES

Source: “Sacramento Systems Planning Study”, By Parsons. 1990

4. Description of System Alternatives

For the Systems Planning Study, a series of system-level alternatives comprising a "no-build," an expanded regional bus system and six fixed guideway "build" alternatives were evaluated within the eight study corridors. The transit modes under study include local and express bus service, busways and high occupancy vehicle (HOV) lanes, commuter rail and light rail transit. Eight system-level alternatives were evaluated for patronage forecasts and cost estimation. Brief descriptions of the alternatives are presented below; detailed descriptions can be found in the Task 3 (Transportation Alternatives) Working Paper.

4.1 ALTERNATIVE 1: NO-BUILD

The No-Build Alternative represents the regional transportation system that would be present in the Year 2010 if no system improvements are made other than those that are already committed with assured funding. For the highway network, this would consist of the defined SACOG 2010 Base Network, as described in Chapter 2. The No-Build transit network includes only those bus and rail improvements defined in the Sacramento Regional Transit District 5 Year Plan 1990-1994. Specifically, the following elements of the 5-Year Plan are assumed:

- Double tracking of the existing LRT line (excluding American River crossing)
- Expansion of the Metro Light Rail Vehicle fleet by 10 vehicles
- Completion of Florin and Gold River Transit Centers
- Addition of various park-and-ride facilities in South County
- Opening of a satellite maintenance facility

For the No-Build Alternative, routes and headways of the bus and Metro services would remain unchanged from those existing in mid-1989. Therefore, no equilibration of passenger ridership and transit capacity was done. Nevertheless, bus operating fleet requirements would be increased over existing conditions due to reduced operating speeds in mixed flow traffic in the future. By 2010, a total of 281 peak pullout buses (excluding spares) are projected to be needed within the region, which is an increase of 86 buses over the 1989 operating level, in order to maintain current headways on each system.

4.2 ALTERNATIVE 2: TRANSPORTATION SYSTEMS MANAGEMENT (TSM)/BEST BUS

Under UMTA Systems Planning procedures, the TSM/Best Bus alternative (referred to as the TSM Alternative) forms the basis against which all other alternatives are compared. The TSM/Best Bus alternative was developed as an extensive bus transit system as illustrated in

Figure 4. Light Rail Transit (LRT) improvements would be limited to service frequency and operational changes on the existing Metro starter line.

Key transit elements of the TSM/Best Bus alternative are as follows:

- Eighty-two all day and 22 peak-period only bus routes would operate. The TSM alternative expands transit coverage within Sacramento County as well as improving services in Yolo and South Placer counties and the City of Folsom.

- Timed transfer points would be provided at 18 locations in the RT service area.

- 15-minute limited stop service would be added on the Watt and Butterfield LRT lines during peak periods. In conjunction with existing service, this would provide 7½ minute peak frequencies to/from the Central City area.

- A new LRT station would be added on the existing Metro Starter line at Dos Rios.

The TSM alternative includes the highway improvements identified for the No-Build Alternative. Expansion of the freeway ramp metering system, along with Bus/HOV bypass lanes, is assumed as depicted in Figure 5. Travel demand management strategies (such as ride-sharing promotions and alternative work hours) are not explicitly modelled.

4.3 ALTERNATIVE 3: BUSWAY/HOV

The Busway/HOV system alternative is illustrated in Figure 6. Busways are included in the following corridors.

- **Natomas-Airport Corridor:** Along Interstate 5 freeway from downtown Sacramento to the Metropolitan airport.

- **Roseville Corridor:** Along Interstate 80 freeway from the end of the Metro station line to Roseville.

- **Folsom Corridor:** Along Route 50 freeway from the end of the Metro starter line to Folsom.

- **South Corridor:** On Route 99 and on Interstate 5 freeways from downtown to Elk Grove.

The busway system is within freeway medians and is two-directional with on-line stations at interchanges. High occupancy vehicles (HOVs) would also be eligible to use the busways (but not the stations). HOV lanes are also included on portions of Interstate 80 and Route 50. The

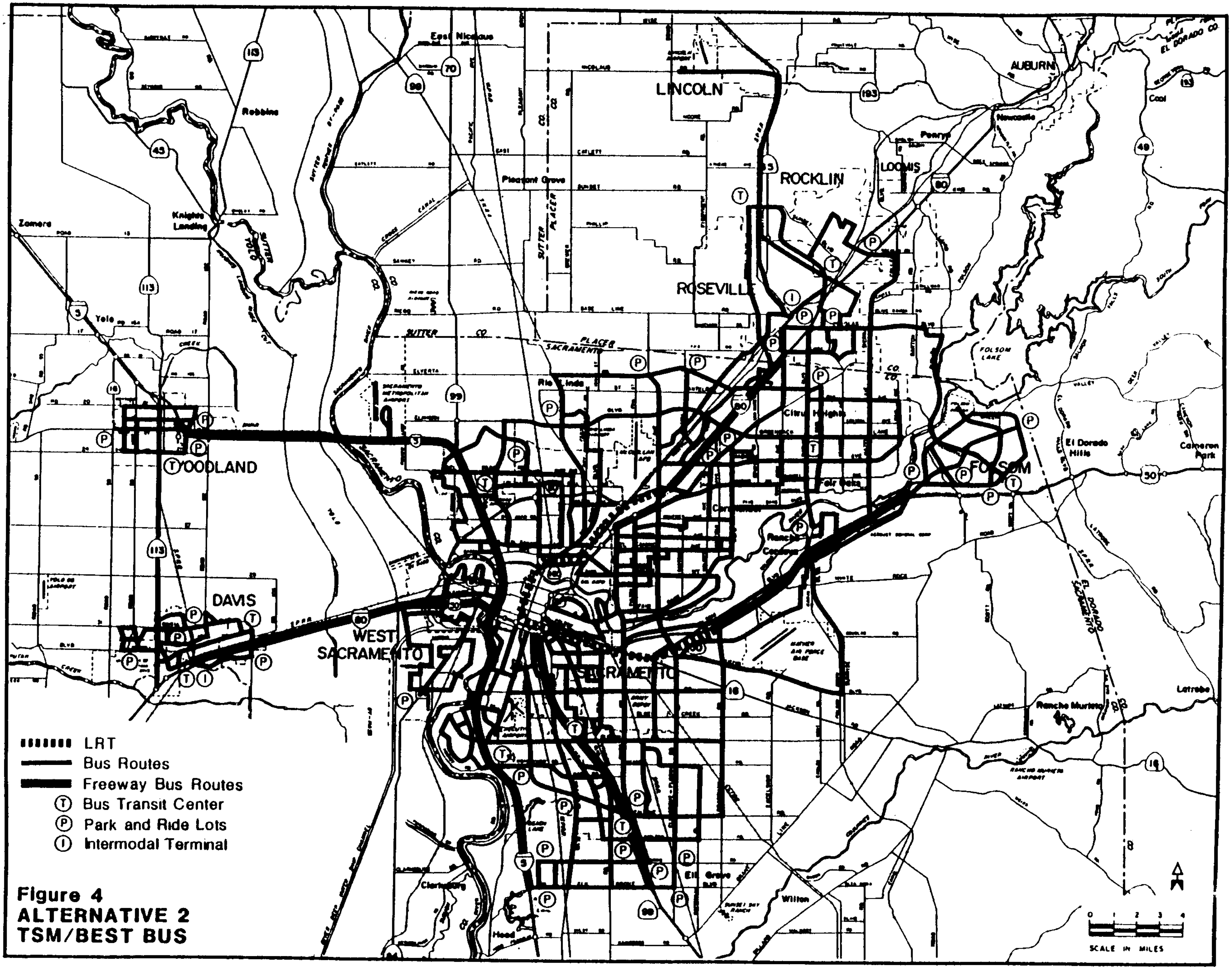


Figure 4
ALTERNATIVE 2
TSM/BEST BUS

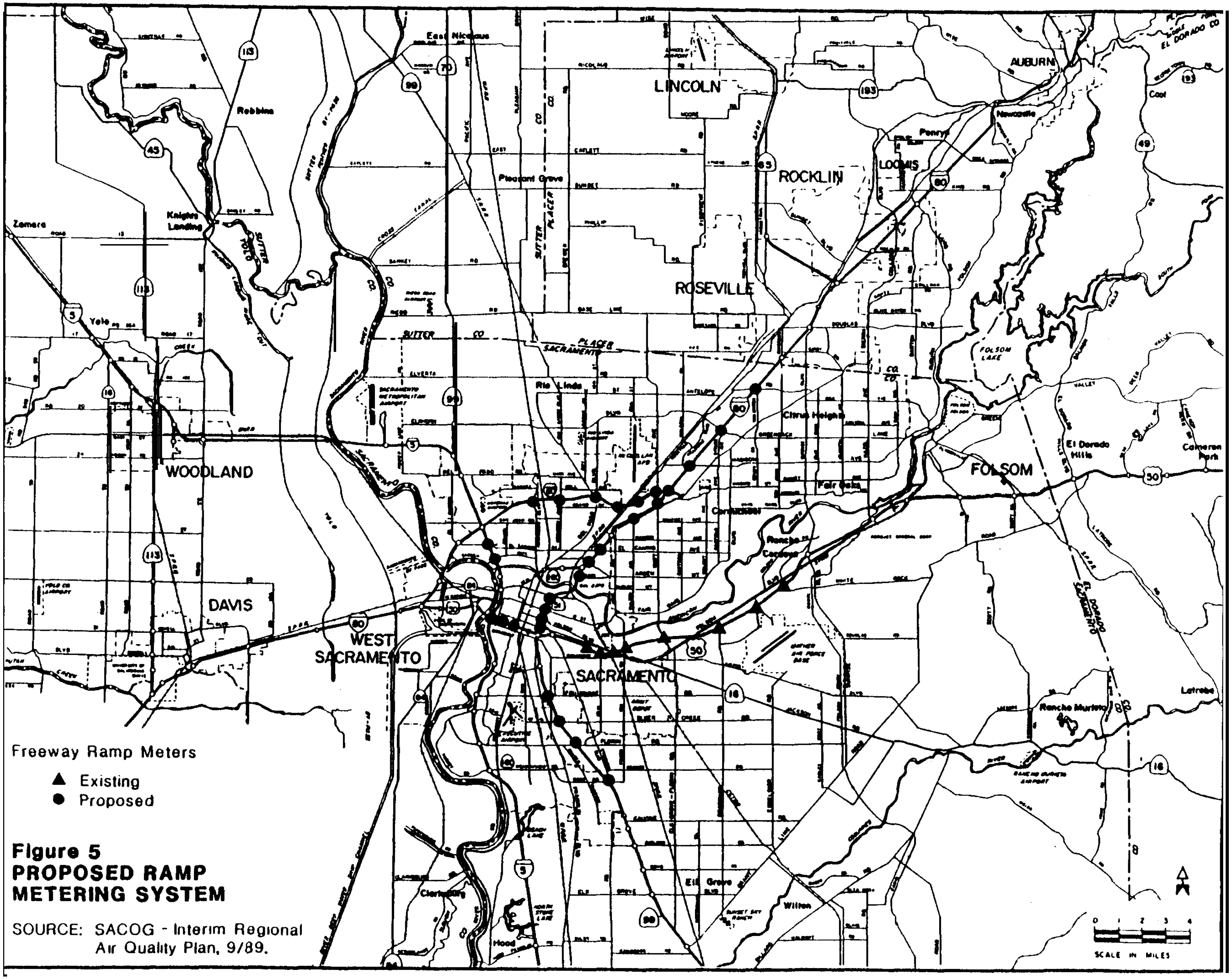


Figure 5
PROPOSED RAMP METERING SYSTEM

SOURCE: SACOG - Interim Regional Air Quality Plan, 9/89.

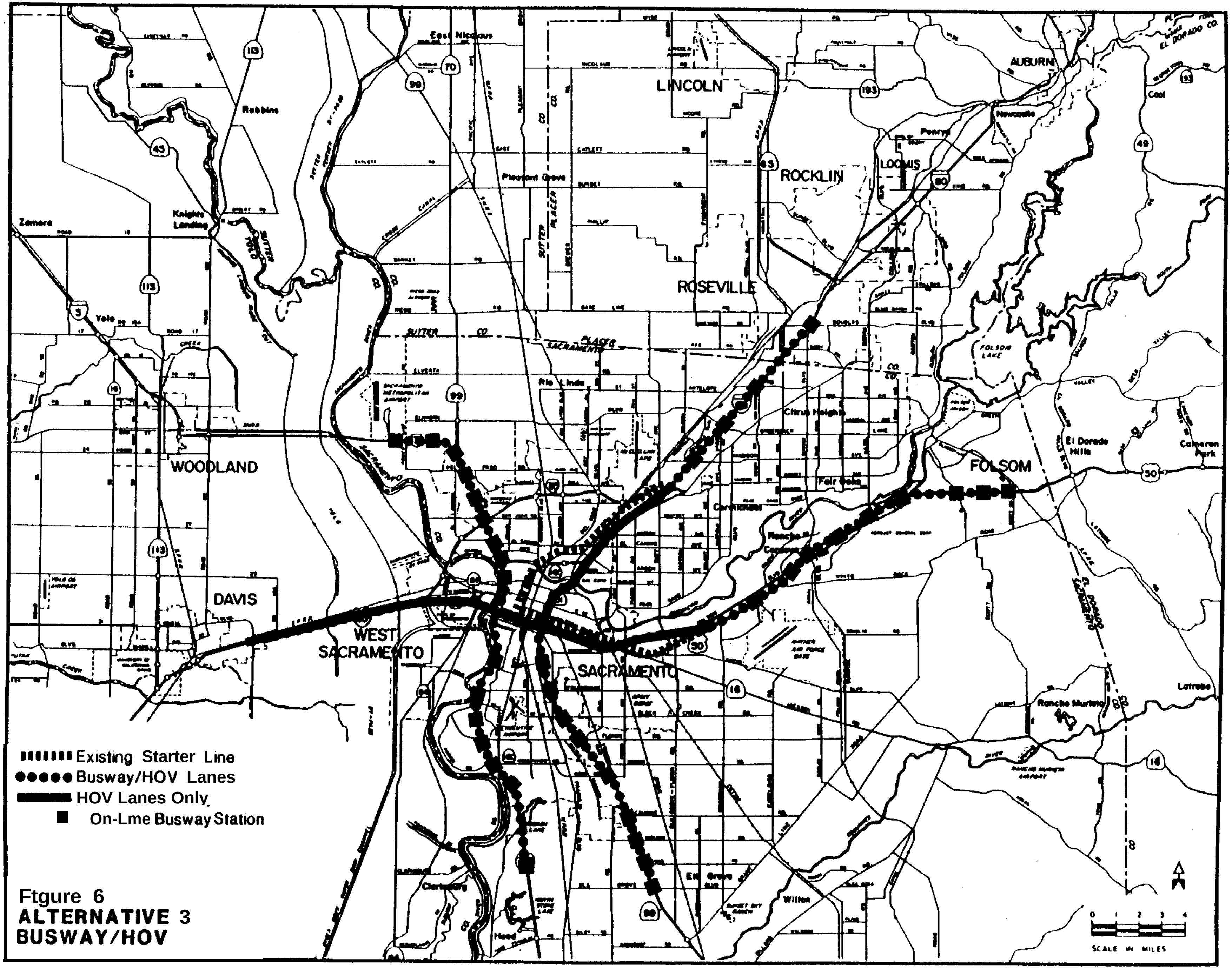


Figure 6
ALTERNATIVE 3
BUSWAY/HOV

minimum vehicle occupancy for HOVs is assumed to be defined as two persons per vehicle. Ramp meter bypass lanes would be provided for buses and HOVs.

4.4 ALTERNATIVE 4: COMMUTER RAIL

The Commuter Rail system alternative is illustrated in Figure 7. It includes peak period service between Auburn and Davis, traversing the Roseville and Davis Corridors.

The assumed operational level is based on Scenario VI of the Intercity Rail Corridor Upgrade Study (ACR 132-Hannigan). Eight stations are included on the line, six of which are east of downtown Sacramento (see corridor descriptions for locations).

The commuter rail system would provide 50-minute headways from Auburn through downtown Sacramento to Davis, and 50-minute headways from Davis to downtown Sacramento in the A.M. peak period. (This consists of three trains during a 2½-hour peak period.)

The commuter rail service is overlaid on the TSM/Best Bus alternative for patronage forecasting.

4.5 ALTERNATIVE 5: MEASURE "A" LRT WITH MEADOWVIEW OPTION

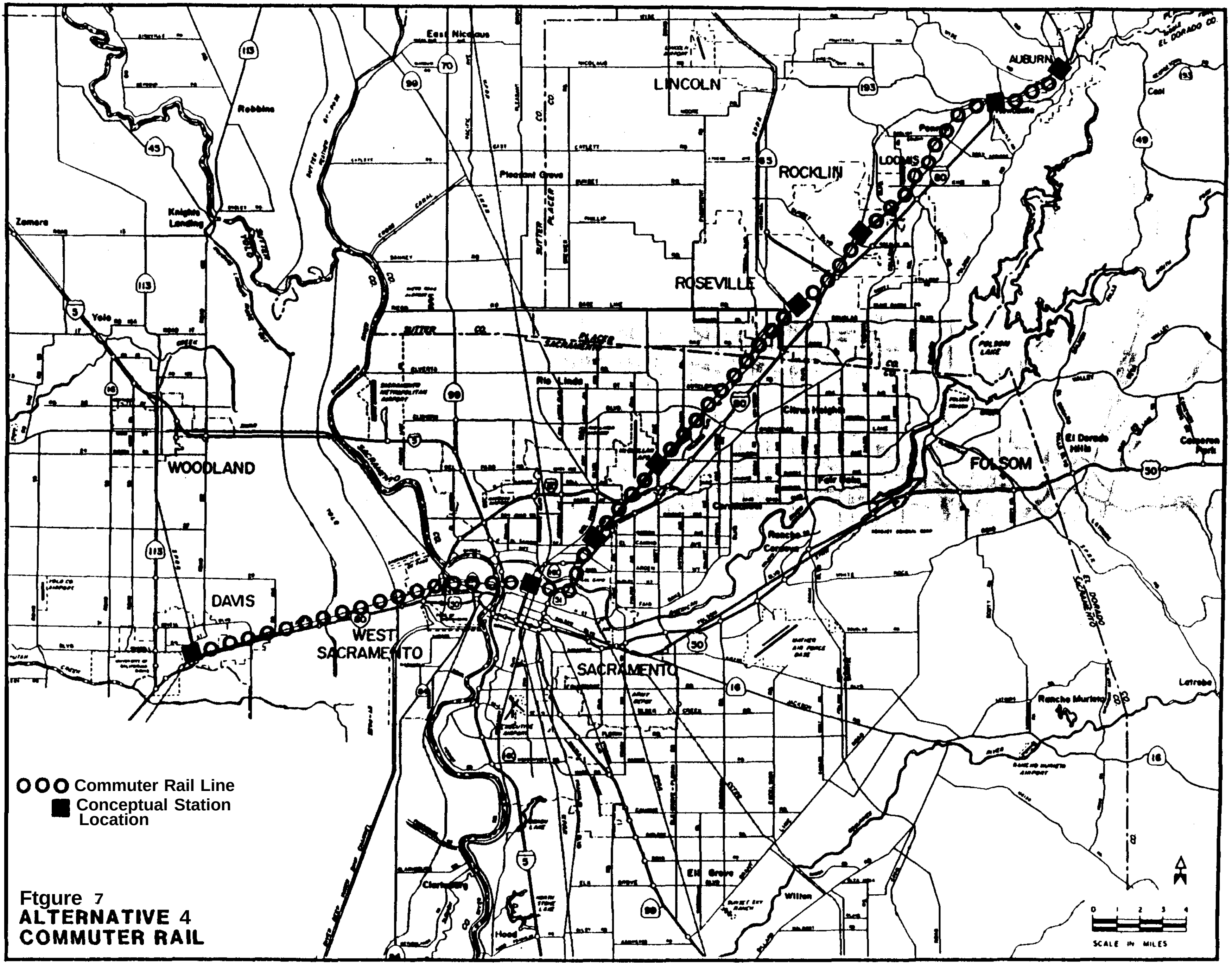
The Alternative 5 LRT system is illustrated in Figure 8. It includes an extension of the Metro starter line in the Roseville corridor to Antelope, an extension of the Metro starter line in the Folsom corridor to Hazel Avenue, and an LRT extension in the South Corridor via the Meadowview area to Cosumnes River College. For patronage forecasting, the LRT system is assumed to operate as four separate two-way lines, with the following headways:

Line	Peak	Off-Peak
A. Antelope - Hazel	15 min.	15-30 min.
B. Starter line	15 min.	15-30 min.
C. Downtown - Cosumnes	15 min.	15-30 min.
P. Starter line/limited stop	15 min.	No service

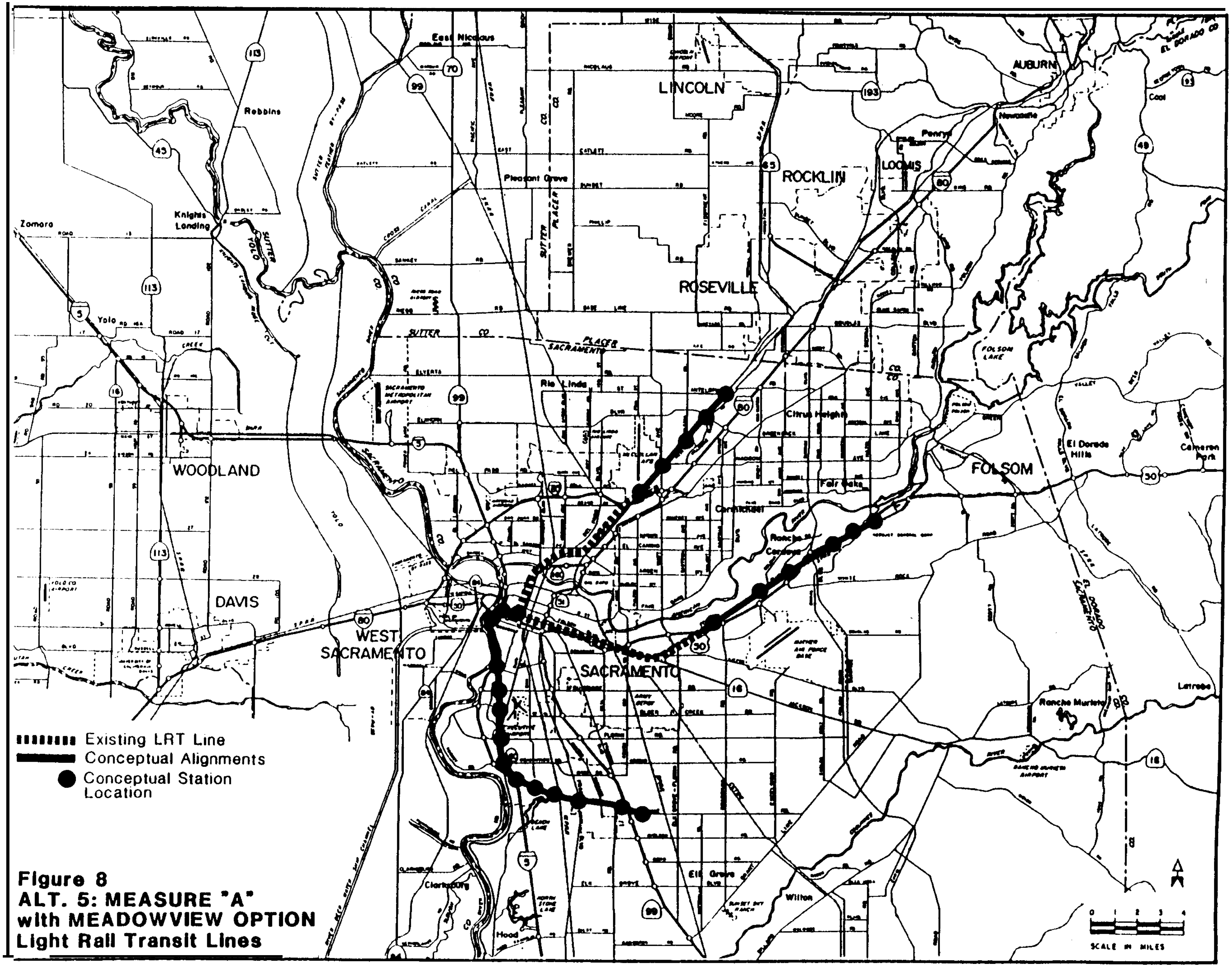
During the transit equilibration process, it was found that these service headways are adequate to accommodate projected peak passenger loads assuming a sufficient number of cars per train.

4.6 ALTERNATIVE 6: MEASURE "A" LRT WITH UPRR OPTION

The Alternative 6 LRT system is illustrated in Figure 9. It includes light rail extensions in the Roseville Corridor to Antelope Road, in the Folsom Corridor to Hazel Avenue, and in the



Ftgure 7
ALTERNATIVE 4
COMMUTER RAIL



▮▮▮▮▮▮▮▮ Existing LRT Line
▬▬▬▬ Conceptual Alignments
● Conceptual Station Location

Figure 8
ALT. 5: MEASURE "A" with MEADOWVIEW OPTION Light Rail Transit Lines

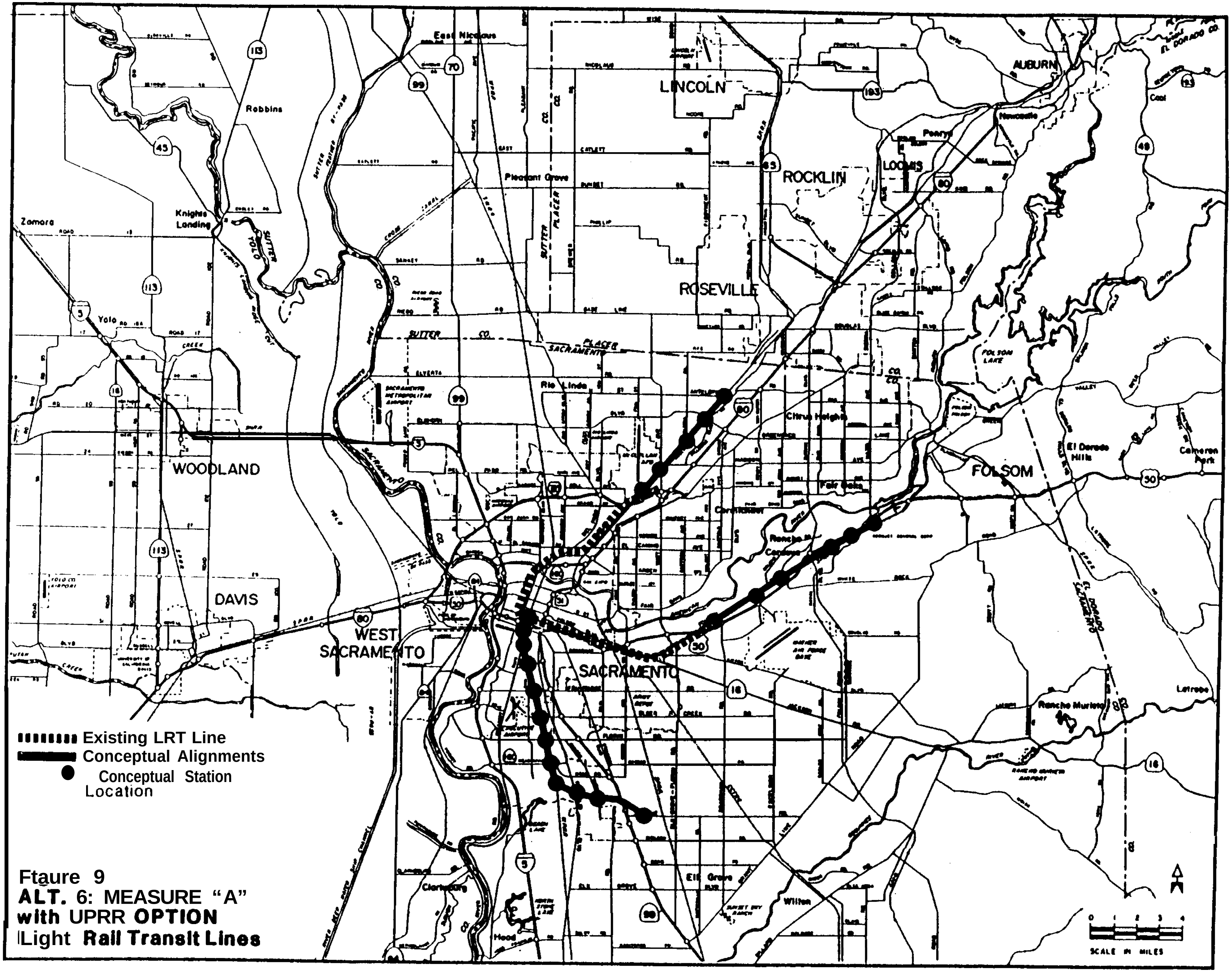


Figure 9
ALT. 6: MEASURE "A" with UPRR OPTION
Light Rail Transit Lines

South Corridor to Cosumnes River College via the UPRR alignment. The system would operate the same as Alternative 5, with four separate two-way lines, except for substitution of the UPRR extension for the Meadowview extension.

4.7 ALTERNATIVE 7: EXPANDED LRT WITH MEADOWVIEW OPTION

The Alternative 7 LRT system is shown in Figure 10. It includes light rail extensions in Natomas-Airport, Roseville, Folsom, Cal Traction, South, Davis and Auburn-Greenback-Sunrise Corridors.

For patronage forecasting, the LRT system is assumed to operate as six separate two-way transit lines with the following headways:

Line	Peak	Off-Peak
A. I-80/Greenback/Sunrise/I-50 Loop	15 min.	15-30 min.
B. Roseville - Cal Traction	15 min.	15-30 min.
C. Davis - Folsom	15 min.	15-30 min.
D. Airport/Natomas - Elk Grove/UPRR	15 min.	15-30 min.
E. Downtown - Elk Grove/SPRR	15 min.	15-30 min.
P. Starter line/limited stop service	15 min.	No service

During the transit equilibration process, it was found that these service headways are adequate to accommodate projected peak passenger loads assuming a sufficient number of cars per train.

4.8 ALTERNATIVE 8: EXPANDED LRT WITH UPRR OPTION

Alternative 8 includes light rail extensions in the Natomas-Airport, Roseville, Folsom, Cal Traction, South, Davis and Auburn-Greenback-Sunrise corridors, as illustrated in Figure 11. The LRT system would be the same as described for Alternative 7, except for substitution of service along the UPRR alignment for Meadowview service.

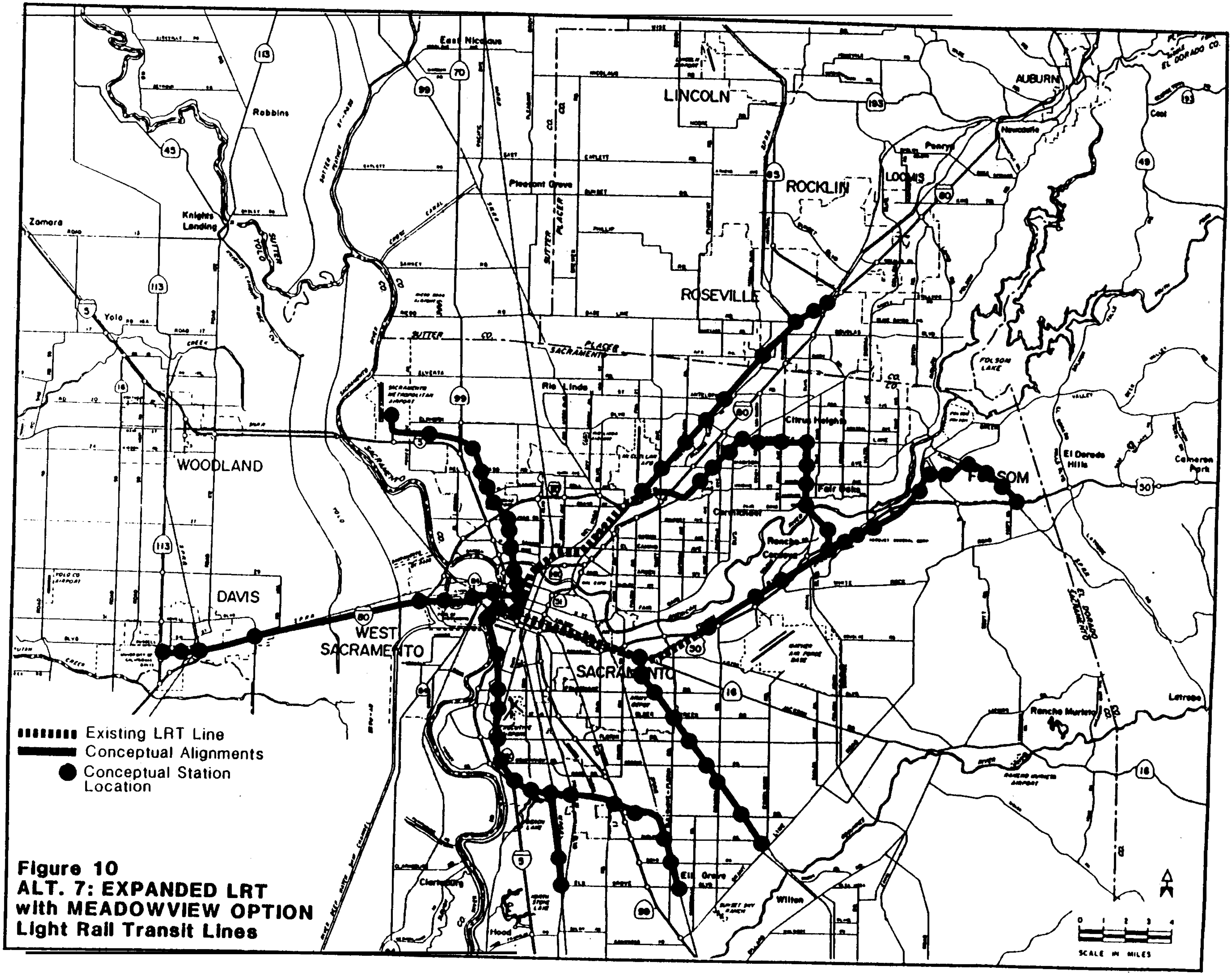
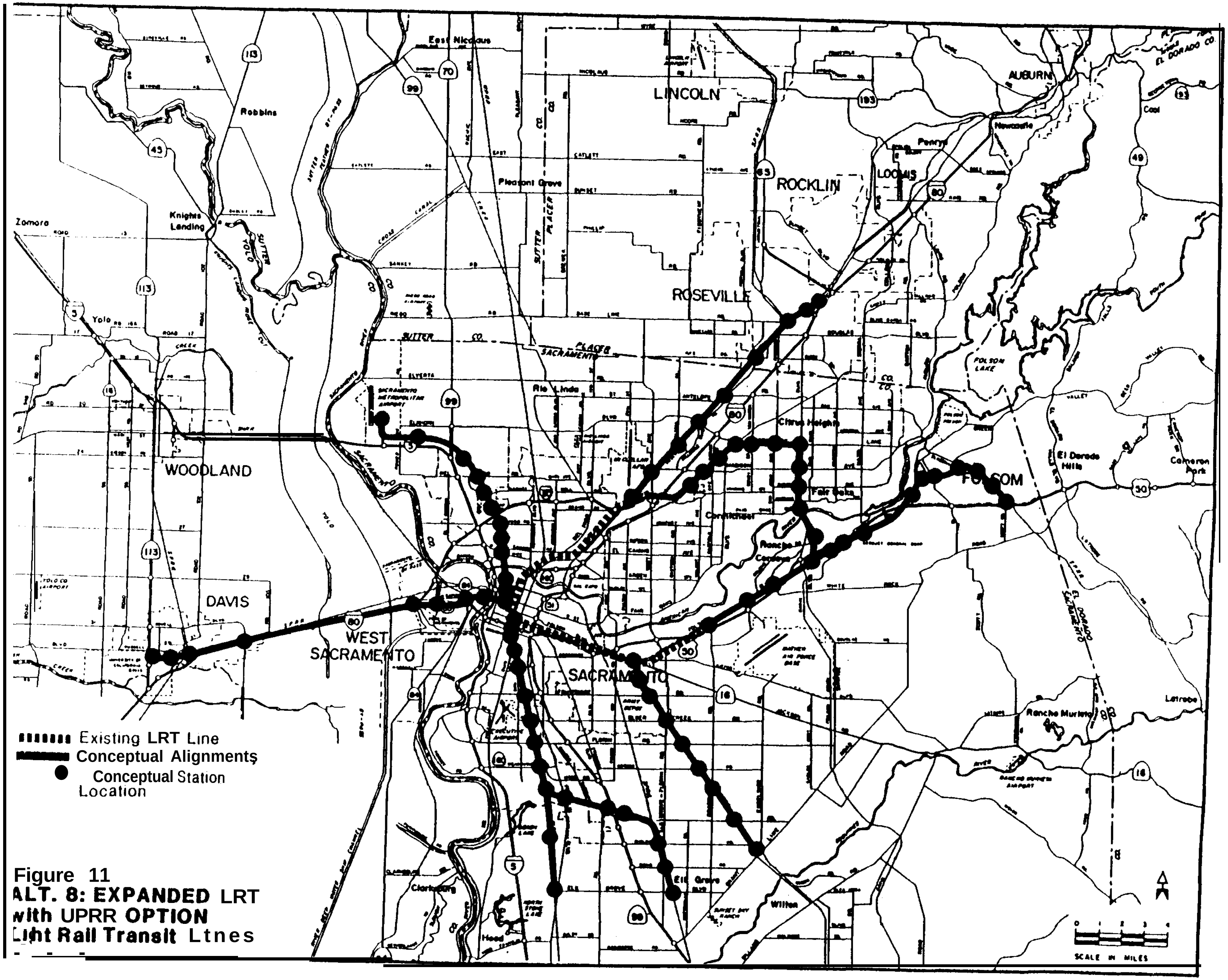


Figure 10
ALT. 7: EXPANDED LRT with MEADOWVIEW OPTION Light Rail Transit Lines



▮▮▮▮▮▮▮ Existing LRT Line
▬▬▬ Conceptual Alignments
● Conceptual Station Location

Figure 11
ALT. 8: EXPANDED LRT
with UPRR **OPTION**
Light Rail Transit Lines

APPENDIX B

Land Use Shifts and Land Use Density Tables

LANDUSE DATA: SINGLE & MULTI-FAMILY HOUSEHOLD SHIFTS

TOD #	SFTOT 1989	MFTOT 1989	SFTOT 2010	MFTOT 2010	SFTOT 2010/A	MFTOT 2010/A	SFTOT DIFF	MFTOT DIFF	SFTOT SHIFT	MFTOT SHIFT	SFTOT SHIF/A	MFTOT SHIF/A
1	2278	928	2406	1610	7.519	5.031	128	682	1	0	0.003	0
2	1971	354	2089	378	6.528	1.181	118	24	16.5	3.5	0.052	0.011
3	1768	446	2035	480	6.359	1.5	267	34	58	21.5	0.181	0.067
4	1686	192	1962	220	6.131	0.688	276	28	651.2	392	2.035	1.225
5	629	551	664	563	2.075	1.759	35	12	255.3	249.9	0.798	0.781
6	1182	1234	2181	1663	6.816	5.197	999	429	152.1	500.5	0.475	1.564
7	336	1	391	0	1.222	0	55	-1	0	76.03	0	0.238
8	20	0	16	0	0.05	0	-4	0	2284	412.1	7.137	1.288
9	4	0	4	0	0.013	0	0	0	102.5	11.39	0.32	0.036
10	68	11	66	13	0.206	0.041	-2	2	124.6	16.75	0.389	0.052
11	822	971	831	981	2.597	3.066	9	10	87.1	734.3	0.272	2.295
12	27	9	23	6	0.072	0.019	-4	-3	0	105.2	0	0.329
13	56	112	114	124	0.356	0.388	58	12	0	25.46	0	0.08
14	1461	263	1512	274	4.725	0.856	51	11	172.9	54.94	0.54	0.172
15	1035	104	1056	106	3.3	0.331	21	2	0	0	0	0
16	469	606	500	647	1.563	2.022	31	41	15.41	2.01	0.048	0.006
17	2572	479	2631	526	8.222	1.644	59	47	0	0	0	0
18	2931	897	2810	878	8.781	2.744	-121	-19	0	359.8	0	1.124
19	2778	1323	3129	1771	9.778	5.534	351	448	44.22	0	0.138	0
20	2721	401	2759	882	8.622	2.756	38	481	0	492.5	0	1.539
21	1225	1048	1525	1628	4.766	5.088	300	580	83.26	167.2	0.26	0.523
22	2714	1046	2753	1373	8.603	4.291	39	327	29.84	886.6	0.093	2.771
23	119	207	110	191	0.344	0.597	-9	-16	0	0	0	0
24	291	200	432	241	1.35	0.753	141	41	40	36.5	0.125	0.114
25	361	651	300	905	0.938	2.828	-61	254	1811	748.5	5.659	2.339
26	350	299	351	279	1.097	0.872	1	-20	45	515	0.141	1.609
27	934	227	1282	355	4.006	1.109	348	128	0	419.5	0	1.311
28	371	128	588	676	1.838	2.113	217	548	4050	1364	12.65	4.263
29	1311	169	1519	214	4.747	0.669	208	45	3510	1292	10.97	4.036
30	6	1	6	0	0.019	0	0	-1	0	0	0	0
31	60	86	58	83	0.181	0.259	-2	-3	0	0	0	0
32	1363	1023	1191	1209	3.722	3.778	-172	186	0	0	0	0
33	1921	836	1740	1255	5.438	3.922	-181	419	249	11	0.778	0.034
34	320	1473	269	1911	0.841	5.972	-51	438	0	0	0	0
35	3602	716	3330	1293	10.41	4.041	-272	577	2588	2604	8.088	8.136
36	2473	321	3434	2031	10.73	6.347	961	1710	2195	1570	6.858	4.906
37	44	1	37	1	0.116	0.003	-7	0	82	118.5	0.256	0.37
38	1317	1671	1263	1860	3.947	5.813	-54	189	99.5	257	0.311	0.803
39	624	1958	649	2252	2.028	7.038	25	294	0	0	0	0
40	3147	1423	2839	2098	8.872	6.556	-308	675	70.5	142	0.22	0.444
41	16	14	11	10	0.034	0.031	-5	-4	0	0	0	0
42	62	2	0	0	0	0	-62	-2	0	0	0	0
43	493	461	804	877	2.513	2.741	311	416	875	1223	2.734	3.823
44	3516	1356	3565	2417	11.14	7.553	49	1061	470.3	444.9	1.47	1.39
45	10	0	1161	1369	3.628	4.278	1151	1369	190.3	1960	0.595	6.126
46	1	0	0	0	0	0	-1	0	1342	2666	4.193	8.332
47	1	0	634	2080	1.981	6.5	633	2080	1650	4229	5.155	13.22

LANDUSE DATA: SINGLE & MULTI-FAMILY HOUSEHOLD SHIFTS

TOD #	SFTOT 1989	MFTOT 1989	SFTOT 2010	MFTOT 2010	SFTOT 2010/A	MFTOT 2010/A	SFTOT DIFF	MFTOT DIFF	SFTOT SHIFT	MFTOT SHIFT	SFTOT SHIF/A	MFTOT SHIF/A
48	0	0	2253	2792	7.041	8.725	2253	2792	9917	2146	30.99	6.705
49	0	0	0	0	0	0	0	0	0	0	0	0
50	5	0	5	0	0.016	0	0	0	0	0	0	0
51	93	0	97	0	0.303	0	4	0	6892	72	21.54	0.225
52	1464	757	2626	1726	8.206	5.394	1162	969	44	64	0.138	0.2
53	2475	1190	2534	1235	7.919	3.859	59	45	4179	928	13.06	2.9
54	1136	815	1242	1213	3.881	3.791	106	398	224	0	0.7	0
55	1575	1120	2859	1679	8.934	5.247	1284	559	1053	1175	3.289	3.672
56	980	37	1384	1932	4.325	6.038	404	1895	840.9	614.4	2.628	1.92
57	1436	35	2319	442	7.247	1.381	883	407	295.5	249.9	0.923	0.781
58	3	0	3343	0	10.45	0	3340	0	51.59	2.68	0.161	0.008
59	10	0	3091	1789	9.659	5.591	3081	1789	13426	2862	41.96	8.944
60	2	0	2359	1567	7.372	4.897	2357	1567	3085	178	9.641	0.556
61	2518	131	2234	217	6.981	0.678	-284	86	425	303	1.328	0.947
62	2082	125	2377	125	7.428	0.391	295	0	0	744	0	2.325
63	519	203	4582	494	14.32	1.544	4063	291	59287	20702	185.3	64.69
64	113	0	123	0	0.384	0	10	0	300	821	0.938	2.566
65	102	0	1121	0	3.503	0	1019	0	7377	2009	23.05	6.278
66	38	0	1084	0	3.388	0	1046	0	1693	19	5.291	0.059
67	1331	730	1340	1058	4.188	3.306	9	328	0	181.6	0	0.567
68	34	0	0	0	0	0	-34	0	4748	0	14.84	0
69	87	0	0	0	0	0	-87	0	0	0	0	0
70	105	0	0	0	0	0	-105	0	0	0	0	0
71	8	0	1192	1198	3.725	3.744	1184	1198	216	235.5	0.675	0.736
72	277	185	310	1836	0.969	5.738	33	1651	48	59.75	0.15	0.187
73	0	0	3463	200	10.82	0.625	3463	200	240.5	0	0.752	0
74	1	0	3998	377	12.49	1.178	3997	377	7182	777.3	22.44	2.429
75	3490	450	3444	1874	10.76	5.856	-46	1424	28.14	24.79	0.088	0.077
76	480	50	553	52	1.728	0.163	73	2	62.31	693.5	0.195	2.167
77	1041	461	1325	873	4.141	2.728	284	412	68.34	172.9	0.214	0.54
78	1067	874	1285	1173	4.016	3.666	218	299	475.7	304.2	1.487	0.951
79	1064	2032	1289	2203	4.028	6.884	225	171	478.4	471	1.495	1.472
80	1829	1601	1762	3080	5.506	9.625	-67	1479	1317	456.9	4.116	1.428
83	3061	692	5821	1823	18.19	5.697	2760	1131	0	0	0	0
84	1155	623	2141	1699	6.691	5.309	986	1076	2515	784	7.859	2.45
85	742	0	4323	395	13.51	1.234	3581	395	3544	255	11.08	0.797
86	156	3	4716	2501	14.74	7.816	4560	2498	8042	748	25.13	2.338
87	2458	503	3928	819	12.28	2.559	1470	316	0	0	0	0
97	10178	8406	17976	14364	56.18	44.89	7798	5958	7798	5958	24.37	18.62
98	10440	3530	18129	8461	56.65	26.44	7689	4931	7689	4931	24.03	15.41
99					0	0	4454	772	4454	772	13.92	2.413
100	564	1634	134	391	0.419	1.222	-430	-1243	0	0	0	0
101	229	1662	26	196	0.081	0.613	-203	-1466	0	0	0	0
102	29	555	12	220	0.038	0.688	-17	-335	0	0	0	0
103	1	397	0	136	0	0.425	-1	-261	0	0	0	0
104	22	848	14	566	0.044	1.769	-8	-282	0	0	0	0
105	3	244	3	275	0.009	0.859	0	31	0	0	0	0

LANDUSE DATA: SINGLE & MULTI-FAMILY HOUSEHOLD SHIFTS

TOD #	SFTOT 1989	MFTOT 1989	SFTOT 2010	MFTOT 2010	SFTOT 2010/A	MFTOT 2010/A	SFTOT DIFF	MFTOT DIFF	SFTOT SHIFT	MFTOT SHIFT	SFTOT SHIF/A	MFTOT SHIF/A
106	10	395	2	81	0.006	0.253	-8	-314	0	0	0	0
107	40	714	64	1171	0.2	3.659	24	457	0	0	0	0
108	7	348	3	199	0.009	0.622	-4	-149	0	0	0	0
109	64	2205	14	512	0.044	1.6	-50	-1693	0	0	0	0
110	198	1823	90	847	0.281	2.647	-108	-976	0	0	0	0
111	168	1438	67	584	0.209	1.825	-101	-854	0	0	0	0
112	459	1162	118	299	0.369	0.934	-341	-863	0	0	0	0
113	382	940	58	139	0.181	0.434	-324	-801	0	0	0	0
114	136	412	25	73	0.078	0.228	-111	-339	0	0	0	0

LANDUSE DATA : RETAIL AND NON-RETAIL SHIFTS

TOD	RET	NONRE	RET	NONRE	RET	NONRET	factoredshift		factored shift	
#	1989	1989	2010	2010	2010/A	2010/A	RET	NONRE	RET/A	NONRET/A
1	620	5517	1196	6778	3.74	21.18	-34.5	592.5	-0.108	1.852
2	146	2206	466	2945	1.46	9.20	210	-8.5	0.656	-0.027
3	487	1289	806	2055	2.52	6.42	637	252	1.991	0.788
4	487	685	638	1063	1.99	3.32	289.5	88.5	0.905	0.277
5	206	2939	284	3190	0.89	9.97	380.5	144.5	1.189	0.452
6	1021	5481	1222	6457	3.82	20.18	314.5	643.5	0.983	2.011
7	49	549	108	801	0.34	2.50	206.5	1010	0.645	3.155
8	508	2454	10	5906	0.03	18.46	218	1487	0.681	4.647
9	309	3948	0	9710	0.00	30.34	397.5	-152	1.242	-0.475
10	229	3630	0	13644	0.00	42.64	109.5	107.5	0.342	0.336
11	418	1349	889	5659	2.78	17.68	718.5	-103	2.245	-0.322
12	73	1773	80	3838	0.25	11.99	39.5	1111	0.123	3.472
13	90	3576	653	3897	2.04	12.18	-2	559.5	-0.006	1.748
14	412	2491	572	2458	1.79	7.68	218	-106	0.681	-0.330
15	19	664	208	753	0.65	2.35	57.5	505.5	0.180	1.580
16	81	2644	388	3164	1.21	9.89	23.5	159	0.073	0.497
17	489	3899	1163	8050	3.63	25.16	31	34	0.097	0.106
18	380	566	623	1595	1.95	4.98	96	322.5	0.300	1.008
19	255	578	303	609	0.95	1.90	12.5	108.5	0.039	0.339
20	325	2176	606	3499	1.89	10.93	152	1442	0.475	4.505
21	125	2270	671	7706	2.10	24.08	14	2367	0.044	7.397
22	547	560	649	705	2.03	2.20	53	58.5	0.166	0.183
23	296	5204	678	10955	2.12	34.23	0	0	0.000	0.000
24	123	2134	344	5485	1.08	17.14	32	137	0.100	0.428
25	911	6315	0	2847	0.00	8.90	221.5	3763	0.692	11.758
26	658	2901	737	3677	2.30	11.49	40.5	2417	0.127	7.553
27	165	1677	544	3177	1.70	9.93	124	173.5	0.388	0.542
28	81	165	89	169	0.28	0.53	365.5	1433	1.142	4.477
29	102	322	338	572	1.06	1.79	133.5	4094	0.417	12.794
30	286	1306	295	1450	0.92	4.53	0	0	0.000	0.000
31	0	0	0	0	0.00	0.00	0	0	0.000	0.000
32	1015	976	1501	1852	4.69	5.79	0	0	0.000	0.000
33	511	785	738	789	2.31	2.47	-141	1771	-0.441	5.533
34	138	420	150	441	0.47	1.38	0	0	0.000	0.000
35	164	569	184	616	0.58	1.93	565.5	449.5	1.767	1.405
36	876	481	889	935	2.78	2.92	318.5	134.5	0.995	0.420
37	34	116	36	124	0.11	0.39	6	24.5	0.019	0.077
38	1240	1635	1361	2036	4.25	6.36	15.5	75.5	0.048	0.236
39	1059	1580	1200	1742	3.75	5.44	13.5	10	0.042	0.031
40	215	1647	264	1908	0.83	5.96	-239	1741	-0.745	5.439
41	300	2950	623	6577	1.95	20.55	0	0	0.000	0.000
42	3	5	3	5	0.01	0.02	0	0	0.000	0.000
43	133	1451	545	7855	1.70	24.55	167.5	5044	0.523	15.763
44	22	282	199	553	0.62	1.73	126	3388	0.394	10.588
45	211	904	470	12114	1.47	37.86	18	6580	0.056	20.563
46	360	450	219	8482	0.68	26.51	487.5	3492	1.523	10.913
47	22	22	0	3949	0.00	12.34	557.5	2059	1.742	6.433

LAND USE DATA : RETAIL AND NON-RETAIL SHIFTS

TOD	RET	NONRE	RET	NONRE	RET	**NONRET**	factored shift		factored shift	
#	1989	1989	2010	2010	**2010/A**	**2010/A**	RET	NONRE	RET/A	**NONRET/A**
48	35	35	79	4885	0.25	15.27	371	4410	1.159	13.781
49	1	1	1	1	0.00	0.00	0	0	0.000	0.000
50	5	10	367	2362	1.15	7.38	0	0	0.000	0.000
51	204	892	520	3410	1.63	10.66	355	2616	1.109	8.175
52	166	998	308	1554	0.96	4.86	-140	631	-0.438	1.972
53	310	716	382	978	1.19	3.06	-225	1252	-0.703	3.913
54	392	1309	520	1860	1.63	5.81	152	10533	0.475	32.916
55	701	769	1178	1343	3.68	4.20	603	2339	1.884	7.309
56	103	675	348	1668	1.09	5.21	142	371.5	0.444	1.161
57	49	72	167	259	0.52	0.81	0	-725	0.000	-2.266
58	2	206	1	236	0.00	0.74	161.5	1259	0.505	3.933
59	57	57	979	3320	3.06	10.38	3028	8151	9.463	25.470
60	4	56	516	1153	1.61	3.60	62	369	0.194	1.153
61	1099	469	1052	1550	3.29	4.84	23.5	13	0.073	0.041
62	175	216	170	328	0.53	1.03	69.5	67	0.217	0.209
63	615	1922	770	3027	2.41	9.46	3923	37788	12.259	118.088
64	1	13	1	15	0.00	0.05	167	372	0.522	1.163
65	3	7	3	8	0.01	0.03	992	536	3.100	1.675
66	1	10	0	12	0.00	0.04	77	423	0.241	1.322
67	0	0	0	0	0.00	0.00	22.5	13.5	0.070	0.042
68	79	2118	347	4653	1.08	14.54	-6	507	-0.019	1.584
69	13	128	57	374	0.18	1.17	0	0	0.000	0.000
70	30	4000	880	7472	2.75	23.35	0	0	0.000	0.000
71	66	3625	0	2550	0.00	7.97	82	101	0.256	0.316
72	711	729	1735	5464	5.42	17.08	108.5	1230	0.339	3.842
73	5	24	0	63	0.00	0.20	-0.5	18.5	-0.002	0.058
74	33	33	0	1962	0.00	6.13	1216	199.5	3.798	0.623
75	566	2239	2360	5552	7.38	17.35	1	4	0.003	0.013
76	8	90	8	95	0.03	0.30	43.5	-31	0.136	-0.097
77	253	500	265	476	0.83	1.49	8	-30.5	0.025	-0.095
78	65	430	81	386	0.25	1.21	-16.5	18	-0.052	0.056
79	4047	610	4285	756	13.39	2.36	163	61	0.509	0.191
80	512	461	537	597	1.68	1.87	38	100	0.119	0.313
81	0	0	0	0	0.00	0.00	0	0	0.000	0.000
82	0	0	0	0	0.00	0.00	0	0	0.000	0.000
83	16	369	635	561	1.98	1.75	0	0	0.000	0.000
84	456	1983	581	3014	1.82	9.42	-2	0	-0.006	0.000
85	232	194	668	1121	2.09	3.50	96	293	0.300	0.916
86	302	1305	1087	6051	3.40	18.91	573	-1	1.791	-0.003
87	627	702	837	1086	2.62	3.39	123	1206	0.384	3.769
97	2020	17309	15870	16511	49.59	51.60	13850	-798	43.281	-2.494
98	2689	19953	6632	33702	20.73	105.32	3943	13749	12.322	42.966
99	299	903	373	1263	1.17	3.95	74	360	0.231	1.125
100	64	384	19	424	0.06	1.33	0	0	0.000	0.000
101	25	780	32	887	0.10	2.77	0	0	0.000	0.000
102	29	2130	138	3162	0.43	9.88	0	0	0.000	0.000
103	1539	2200	1921	3963	6.00	12.38	0	0	0.000	0.000

LANDUSE DATA : RETAIL AND NON-RETAIL SHIFTS

TOD	RET	NONRE	RET	NONRE	RET	NONRET	factored shift		factored shift	
#	1989	1989	2010	2010	201 O/A	201 O/A	RET	NONRE	RET/A	NONRET/A
104	58	4116	322	6464	1.01	20.20	0	0	0.000	0.000
105	97	6210	97	6210	0.30	19.41	0	0	0.000	0.000
106	1058	2860	445	3799	1.39	11.87	0	0	0.000	0.000
107	354	1661	354	1544	1.11	4.83	0	0	0.000	0.000
108	430	1537	434	3285	1.36	10.27	0	0	0.000	0.000
109	40	405	69	223	0.22	0.70	0	0	0.000	0.000
110	60	1061	60	853	0.19	2.67	0	0	0.000	0.000
111	80	600	161	437	0.50	1.37	0	0	0.000	0.000
112	38	135	68	285	0.21	0.89	0	0	0.000	0.000
113	137	1053	267	1024	0.83	3.20	0	0	0.000	0.000
114	41	534	112	2052	0.35	6.41	0	0	0.000	0.000