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Effects of Increased Highway Capacity on Travel Behavior

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

AIR RESOURCES BOARD
Research Division

Effects of Increased Highway Capacity on Travel Behavior

Final Report

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ABSTRACT

Changes in highway capacity change travel behavior. Short term impacts may include changes in route choice, the time of day trips are made, mode choice, trip frequency, trip chaining (the way trips are linked together), and destination choice. Longer term impacts include changes in auto ownership, residential location, choice of workplace location, and land development patterns. These changes all occur against an ever shifting background of economic, demographic, and transportation pricing changes affecting the population as a whole.

Although there has been considerable research and debate on this topic for many years, the complexity of the problem has frustrated any definitive answers-- answers that are important because they affect our ability to predict impacts of new transportation improvements on the demand for facilities, congestion levels, vehicle miles of travel, and harmful vehicle emissions.

The purpose of this study has been to develop a better understanding of the effects of new high capacity on travel behavior, assess current travel forecasting model procedures against that enhanced understanding, recommend improvements to current understanding, and identify areas for further research. This work gives the public a better understanding of the significance of this issue, and transportation and air quality analysts a better sense of how to assess the induced travel impacts of new highway capacity.

A three-part approach has been used to accomplish this: the use of case studies of historic changes; the application of travel and economic theory to the problem; and a household survey of household travel behavior and activity patterns. The literature review and survey showed that changes in the time at which people make trips (trip scheduling changes) and the choice of the highway route driven are the two most important effects of increased capacity. A Dutch study found that these two effects account for over 90% of the observed increase in traffic volumes on a new freeway in a congested area. Changes in mode choice (transit versus auto), trip destination, and the frequency with which trips are made, turn out to be secondary effects of increased highway capacity. The household survey conducted as part of this study found that a five minute time savings would cause survey respondents to make an extra stop or to change the destination for about four percent of the their trips.

The study concludes with recommendations for improvements to current travel demand modeling practices and for further research into the travel behavior effects of new capacity.

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SUMMARY AND CONCLUSIONS

The Importance of the Issue to Clean Air and Transportation

State and local governments spend several billion dollars a year on new road improvements to reduce congestion, improve safety, and provide for the economic development of the state. It has also been claimed that new road capacity, to the extent that it reduces speed variations (stop-and-go driving) and allows vehicles to travel 35-45 miles per hour, will also improve air quality. This claim has been challenged by others, who maintain that any such benefit of new road capacity will quickly be negated by new travel that will offset any improvement in the emission *rate* (per vehicle mile) due to the capacity increase. Disagreements arise as to whether this effect exists, and if it does, what its significance is.

Study Purpose

The purposes of this study were to:

- Improve the current understanding of the effects of increased highway capacity on travel behavior
- Determine if increases in highway capacity do affect the number of trips per household
- Assess the magnitude and importance of this effect
- Recommend enhancements to conventional travel forecasting techniques to better model the effects of increased highway capacity on travel behavior.

How New Highway Capacity Can Affect Travel Behavior

Increased highway capacity may affect travel in a number of ways. New capacity typically reduces congestion in urban areas, resulting in shorter travel times during some or all of the day, and a less stressful driving experience. These reduced travel times have been demonstrated to have these effects *in the short term*:

- The choice of the route (streets/highways) taken. This effect has been found to be consistently important in the literature.

- The scheduling of the trip (time of day the trip starts/ends). This effect has also found to be consistently important in the literature; new highway capacity causes travel to shift from off-peak or "shoulder" transitional times, to the peak periods of travel.

- The choice of the travel mode used (e.g., carpool, transit, drive alone). This effect has been shown to be a much weaker impact than the two noted above, but still important, especially as a result of longer term shifts in auto ownership and land use patterns.

- The frequency with which the trip is made. The literature has been inconclusive on this topic, with some studies indicating significant impacts, and others indicating little or no measurable impact. Therefore, this impact became one of the primary issues studied in this project.

- The linking together of trips with several destinations (sometimes known as "trip chaining" or "trip tours"). This appears to be an important impact, but has proven difficult to measure.

- A change in the choice of the destination of a trip; likewise, this impact has proven difficult to measure.

Most investigations of the effects of new highway capacity have been facility-specific "before and after" studies. One of the principal conclusions from the present study is that it is nearly impossible to use this approach to isolate the effects of new highway capacity on induced trip making. There are too many extraneous factors that can affect the results, including the availability of alternative modes and routes in each corridor; the condition of the local economy (growing or stagnant); zoning; and natural constraints to development. These factors not only affect the conclusions but also limit the validity of extending these results to other situations and locations. These factors have frequently led prior researchers to come to opposite conclusions.

However, one important conclusion emerges consistently throughout the literature: the elasticity of demand is nearly always less than one, or as economists would say, inelastic. Inelasticity does *not* imply that there is no response, rather, it implies that the percentage change in trips made will be smaller than the percentage change in travel time.[1] The implication of this conclusion is significant: if one hypothetically doubles the number of lanes on a freeway, or the number of lane-miles in a region, *the vehicle miles of travel will increase, but by less than doubling, all other factors remaining constant.* This seemingly trivial conclusion is actually quite significant, for if it were not true, increasing capacity could actually worsen congestion in the long run. This conclusion refutes the two most polar opinions held on the topic of induced demand. We therefore conclude that new highway capacity will not reduce congestion and harmful emissions as much as some proponents of highway widening claim, *but* it will not induce as much new traffic as some opponents of new capacity claim-- the net effect of new highway capacity will be reduced congestion.

In the longer term, new highway capacity may influence:

- The number of autos owned
- The location of the residence
- The location of where a person finds employment
- The choice of expansion areas for businesses and government

Economic and location theory predicts that reduced highway congestion should increase auto ownership, although available evidence suggests that increases in personal incomes have a much more powerful effect. Theory also predicts that new highway capacity should have the effect of dispersing residential development over a wider area. Many of these impacts are already accounted for in current transportation/land use forecasting practices in California's largest metropolitan areas. The four largest metropolitan areas currently have urban development models which take into account changes in land use patterns induced by changes in accessibility caused by new highway capacity.

[1] For example, someone who experiences a 10% reduction in travel time due to new highway capacity, who then increases his or her weekly trips by 3%, would be exhibiting inelastic travel demand with respect to travel time.

How Well Does Current Practice Address Induced Traffic Growth?

All urbanized California counties currently have computerized transportation forecasting models that are used to assess the impacts of major new transportation facilities. These models are of varying degrees of sophistication, depending on the size and complexity of the study area. The four major metropolitan areas of the state, Sacramento, San Francisco, Los Angeles, and San Diego, have the most sophisticated capabilities. *All four areas now have land use projection models which incorporate transportation and accessibility as part of the forecasting process.*

Where current models now are most deficient is in the area of predicting trip frequency. None of the metro transportation models directly allows for a change in the number of household trips made as a function of accessibility, although the San Francisco Bay Area does use an indirect method of accounting for this impact.

This research is significant for at least two reasons. It has implications for the attainment of air quality goals, and for providing for appropriate capacity to meet growing travel demands in California. Current practice is to use static trip generation models, in which the number of trips generated by each household is not influenced by the congestion on the highways around it. This practice *may* introduce a systematic bias in the travel forecasts in which too little demand will be projected, and possibly too little capacity. This will result in more travel delay and facilities that are not of optimal size.

Results of Travel Survey

As part of this study, almost 700 Californians in the San Francisco and San Diego urban areas were interviewed regarding their existing travel behavior, activity patterns, and hypothetical behavior under changes in travel time. For the amounts of travel time savings likely to occur in most capacity increasing projects-- five to 15 minutes each way-- the respondents indicated considerable resistance to changing their travel habits.

- Approximately 90% to 95% of the trips would be unchanged or would have only been re-scheduled to another time in response to travel time increases and reductions of 15 minutes or less. Re-scheduling of trips has a relatively greater impact on congestion than it does on air quality.

- A time savings of five minutes would generate extra stops for about three percent of the trips where this time savings was offered. This percentage increased to five percent when 15 minute time savings were offered. The average across all time savings offered was three percent.

- Over 35% said they would make no changes in their travel habits even when faced with a change of 15 minutes in one way travel time. Another 20 to 40% would simply change the scheduling of their trip, either by arriving earlier or later, and making no change in the departure time to compensate for or take advantage of, the travel time increase or decrease.

- Higher time increases and decreases had a greater effect on traveler responses than lower amounts of time changes. However, given that only 13% of trips are greater than 30 minutes in length, it was not realistic to ask the great majority of the respondents about time savings of greater than 15 minutes.

- The respondents tended to react slightly more strongly to *increases* in travel time than to decreases. Respondents when faced with a travel time increase would try to adapt by changing mode, destination, and route for a higher percentage of the trips than if they were offered an equal amount of time decrease.

Conclusions and Recommendations

This study attacked a longstanding problem of tremendous complexity. Some of the recommendations for action that emerge from this study are:

- Current travel forecasting practice probably results in an underprediction of three to five percent in the number of trips that may be induced nearly immediately by *major* new highway capacity projects. Where a project is expected to yield travel time savings of more than five minutes for a large number of trips, adjusting of travel demand upward to reflect induced travel is probably warranted.

- A key impact of new highway capacity is temporal shifts in demand (trips formerly made in the off-peak moving to the peak periods). From the highway user's perspective, this is not necessarily bad, since it simply means that he or she can make a trip in response to personal needs rather than traffic conditions. On the other hand, it will affect the congestion, speeds, and emission estimates produced by travel models. There is a strong need to develop better models to predict peak spreading/time of day of travel.

- Canada provides an interesting contrast with the U.S., because it shares many social and demographic characteristics with the U.S., but never completed a major system of urban freeways. The supply and demand for transit in larger Canadian cities is considerably greater than in comparably sized U.S. cities. Canadians typically have commuting distances 25% shorter than Americans, and live in more compact urban areas. However, due to slower travel speeds, Canadians spend about the same amount of time each day commuting as Americans do. This tends to support the hypothesis that workers may have a relatively fixed budget of their time they are willing to allocate to commuting, and are resistant to spending more (or less) time in daily commutation.

Not surprisingly, there were some questions that we could not answer in this study. Section 7.2 covers the areas for further research. They include: expanding the survey in the future to cover more households in more areas of the state; developing alternative survey mechanisms that can assess the possible interactions between household members of changes in travel times; and assessing how difficult-to-quantify factors (such as stress) may influence travel behavior when congestion is reduced.

It seems logical to presume that a 30 minute drive in stop-and-go traffic would be perceived differently from a 30 minute drive in free flowing traffic, but our survey method was not able to distinguish between the two. Based on a small sample of commuters in Orange County, Novaco, 1991 [1] found that most (though not all) drivers found commuting in congested traffic far more stressful than commuting in uncongested traffic. If this is true, it suggests that the results of the travel survey conducted here could underestimate the true effects on tripmaking of reducing congestion.

1. Introduction

Few transportation issues engender more controversy than the effects on traffic and travel demand of adding new highway capacity. The intent of new highway capacity is to reduce traffic congestion and improve automobile travel times, and in some cases, improve air quality. These changes in turn affect travel behavior by affecting peoples' choice of modes of travel, their choice of destination, and their choice of travel route.

Less well known is how travel time changes caused by capacity increases might affect total travel demand, especially trip generation (i.e., the number of trips made per person or per household). The magnitude of this effect on trip generation is particularly unclear. Addressing this issue was one of the primary purposes of this project.

1.1 Project Objective

The objectives of this research project were:

- To improve the current understanding of the effects of increased highway capacity on travel behavior; and
- To recommend enhancements to conventional travel forecasting techniques to better model the effects of increased highway capacity on travel behavior.

1.2 Research Approach

The research objectives were accomplished through a combination of literature review, supplemental case studies, and a household survey of traveler behavior.

The research proceeded in the following sequence:

1. Literature review.

2. Three case studies of highway capacity additions in California were examined, using secondary data (i.e., available counts).
3. A household survey was then conducted to improve the understanding of how travelers will respond to increases in highway capacity and travel times.

4. The results of the above steps were related to the conclusions reached from a theoretical perspective.

5. The conventional travel forecasting techniques currently used by the major metropolitan planning organizations (MPO's) in California were briefly assessed.

6. Recommendations were made for improving the ability of conventional travel forecasting models to forecast the impacts of increased highway capacity.

A technical advisory committee (TAC), consisting of technical experts from the California Air Resources Board, Caltrans, the San Francisco Bay Area Air Quality Management District (BAAQMD), and the Southern California Association of Governments (SCAG), provided additional advice and assistance to the principal investigators in the conduct of this research project.

2. Literature Review

2.1 Introduction

This chapter reports on the results of a literature review of the effects of increased highway capacity on observed travel behavior. This review was conducted to study what available evidence there had been of travel changes due to new capacity, and also to help in developing the travel behavior survey discussed in Chapter 3. Several of these studies had significant limitations or qualifications, and did not conclusively answer the questions related to this research project. The survey was therefore developed to fill in some of the gaps in the knowledge revealed by the literature review.

There have been many investigations into the question of travel impacts of new highway capacity. Most have been facility specific "before and after" studies. This research approach suffers from significant limitations, as discussed in Section 4.4. Some studies have looked at regional travel and attempted to identify long term relationships between daily vehicle miles of travel (VMT) per capita[2] and lane-miles of capacity, but these studies likewise suffer from the qualification that they attempt to describe a complex metropolitan area using just two variables.

2.2 Studies of the Travel Impacts of Highway Capacity

These studies generally have looked at how traffic volumes measured in the field have changed in response to the construction of new highway capacity. In some cases traffic counts have been supplemented with roadside interview or home interview surveys. A few investigators have attempted to fit regression models for predicting regional VMT increases that result from regional increases in highway capacity. A large number of relevant studies were reviewed in preparation of this report (Chapter 9, Bibliography). However, only a few of the most pertinent studies have been included in the subsections below. This was done in the interest of brevity, and also because some of the studies are actually reviews of several other prior studies.

[2] The metric equivalent of VMT is VKT (vehicle kilometers travelled). To obtain VKT, multiply VMT by 1.6.

2.2.1 Dobbins, et al., *The Air Quality Impacts of Urban Highway Capacity Expansion*

Dobbins, et al. **[2]** presents a comprehensive review of current literature on this topic. The various studies are grouped into "facility specific" studies, "area-wide" or regional studies, and modeling studies.

<u>Facility Specific Studies</u>: The report summarizes the results of several studies of the traffic generation impacts of road projects by Jorgensen **[3]**, Frye **[4]**, Pells **[5]**, Addison **[6]** and others. Many of these studies are "before and after" studies of the new or improved roadway taken over various lengths of time; and some attempt to infer how traffic would have evolved had the project not been implemented. Some studies made comparisons of traffic growth with such related variables as gasoline sales, while others investigated growth across a number of screenlines. At least one study used the technique of driver interviews to determine the amount of traffic on the new facility that represented "new" travel.

The various techniques and study locations yielded a wide range of estimates of induced and diverted traffic, ranging from 0-30% in the year following the improvement, and up to 80% four years after implementation. The differences may be due to major differences in the time frames evaluated, different techniques for accounting for land use growth, and variations in the conditions in each corridor. Jorgensen looked at a 10 year period and used a regression relationship based on gasoline sales to account for growth. Addison looked at a twenty year period and suggested that traffic increases not accounted for by standard traffic model forecasts were caused partly by induced demand. Others like Frye looked at impacts within the first four months of a facility's opening.

These facility-specific studies generally did not identify the causes of the traffic increases. However, Pells does report the results of one driver survey of 184 drivers using the new Rochester Way Relief Road which found that 80% of the drivers on this new facility were diverted from other routes, 5% were shifted from other modes, 5% were shifted from other destinations, and 10% were more frequent trips. As interesting as these results might be, they unfortunately are of limited usefulness since these proportions would vary significantly in other corridors depending upon the mode and route options available to drivers in other corridors.

Area Studies: Area-wide studies by Koppelman [7], Payne-Maxie [8] and others correlated VMT to highway capacity across different cities. These studies developed various regression models that correlated levels of highway capacity to total VMT in different cities. These studies however are all based on cross-sectional studies without time-series data to indicate how demand and supply correlate over time.

Some studies attempted to determine an elasticity (see sidebar) of VMT on the basis of lane-miles of facility. A study by Payne-Maxie *et al.* in 1980 using 1975 data for 54 metropolitan regions across the country looked at the impact of beltways; beltways are loop or "ring" roads that go around the central business district in a circular or square configuration, typically at a distance of 5-15 miles from the CBD. They estimated that one additional freeway mile of beltway generates 85 additional daily VMT per thousand population, while an additional mile of other type of freeway generates 18 additional VMT per thousand per day.

Dobbins, *et al.* found that these studies estimated elasticities (see sidebar, next page) in the range between +0.10 and +0.80 for changes in VMT in respect to lane-miles. As with the facility based studies, the range of the estimated impact is large, and Dobbins notes that this may be attributed either to limited data sets and/or methodological shortcomings.

Elasticity of Demand

Elasticity **is the relationship of one variable to another, where the two variables are expected to have a causal relationship (X causes Y to happen). A classic example is the price of a good, and the amount of it consumers demand: a price increase typically causes a reduction in the demand for a good.**

Elasticity expresses the percentage change in one of the variables with respect to the other. For example, if gasoline prices increase by 10% and as result, gasoline sales (total gallons sold) decrease by 3%, the elasticity is said to be (10 / -3) = -0.3.

Elasticities do not have to be calculated with prices; any two variables that are related can have an elasticity computed, provided there is adequate data. The computation assumes that all other variables influencing the relationship remain the same, what economists call the *ceteris paribus* assumption.

Elasticities of less than one are referred to as *inelastic* in nature, while those with an elasticity greater than one are called *elastic.*

Dobbins also developed a model based on time series data for state highways in California that showed that every ten percent increase in state highway lane mileage was accompanied by a two to five percent increase in VMT on state highways. The effect was found to increase strongly with time. This regression model, like all such models, however merely illustrates the correlation of supply and demand but not necessarily the directionality of the effect. How much of the road construction is a governmental response to increased VMT rather than an initiator of increased VMT?

<u>Studies Based on Regional Transport Models</u>: Dobbins cites only two studies of the many conducted using regional transport models, pointing out that most regional models do not include mechanisms for evaluating induced travel. One of the studies conducted using the STEM model in London, U. K. investigated an increase on London's inner beltway, the North Circular Road. The model projected a regional increase of one percent due to the improved facility, with increases in certain boroughs exceeding five percent. Studies by Ruiter, *et al*, investigated the traffic inducing effects of an extension of State Route 24 (SR 24) in Alameda and Contra Costa Counties in California. The extension, consisting of 69 new lane-miles of freeway and ramps, was estimated to induce a 0.33% increase in Bay Area VMT due to a 0.88% increase in areawide capacity. A second study by the same team investigated the effects of widening 13 miles of freeway to create an additional 50 lanes-miles. This study showed a similar increase in peak hour VMT, and there was a slight decrease in daily VMT.

Dobbins's summary of the state-of-the-art is worth quoting here:

In sum, current evidence on the impact of roadway capacity increases of traffic and travel in urban areas is considerable in quantity, particularistic in orientation, varied in methodology, and fragmented in theme. The direct impacts of major projects can -- like a strong radio signal -- be readily discerned, but as the signal dissipates over space and time, it is easily lost in the "background noise" of other processes influencing urban growth and change. Researchers have tried different means -- from statistical analysis aimed at distinguishing signal from noise, to recreation of the signal in the noise-free environment of a computer model, to consultation with experts attuned to the local environment -- to deal with this problem. The outcome of these efforts is a set of interesting, but isolated, readings. A coherent picture has yet to emerge.

2.2.2 Ruiter *et al., The Vehicle Miles of Travel-Urban Highway Supply Relationship*

Ruiter, *et al.* investigated the impacts of both a freeway extension and a widening project through a complex modeling procedure. Their conclusions regarding the linkage between highway supply and demand were as follows:

> *The complexity of the causal linkage between highway supply and VMT has two important consequences: first, the direction of VMT changes because a given highway supply change can vary; second, there are many variables that affect both the direction and the magnitude of VMT changes. In order to quantify the relationship, all of the following variables must be considered:*
>
> - *The type of highway supply change. Many reasons suggest that such changes as new freeway construction, freeway expansion, arterial street improvements, high-occupancy vehicle incentives, and pricing policies (tolls) can have major differences in their impacts on VMT.*
> - *The scale of the highway supply change. VMT changes per unit of capacity added are likely to decrease as the number of capacity units increase.* [In other words, if the area already has a large amount of capacity, the relative impacts of a one percent increase are likely to be of a smaller magnitude than if the area has very little capacity]
> - *The context within which the supply change takes place. Highway and transit travel patterns, levels of congestion, alternative travel routes, land uses, and socioeconomic characteristics in the corridor containing the facility, and the orientation of this corridor (radial versus circumferential, for example).*
> - *The time scale. Short-run changes (before changes in land use have time to occur) versus long-run changes.*

The study also developed the following findings for the two highway projects that were evaluated:

> - *In the freeway construction case, VMT increases as highway supply increases, both in peak and off-peak periods. In the freeway*

expansion case, peak-period VMT increases are offset by off-peak periods; they have quite different impacts on VMT.

- *In absolute magnitude, off-peak VMT changes dominate peak-hour changes. In percentage terms, however, peak period changes are more significant.*

- *Although VMT increases for one test facility and remains essentially unchanged for the other, VMT-related impacts for both cases generally improve when studied at the urban area level. Measures of urban mobility, quality of travel service, air quality (with the exception of the relatively critical level of NO_x pollutants), fuel consumption, and travel safety all are improved at this level.*

- *The common practice of expressing the relationship of VMT and highway supply as a constant elasticity of VMT with respect to average highway speed is potentially misleading."*

The report concludes that the primary effect of new highway capacity is in the peak period of the new facility; an increase on the VMT of roads perpendicular to the route (which provide access to it), and a reduction in VMT outside on routes parallel to the improvement project (as well as outside the project corridor, because of diversion into the corridor). However, he concludes that the net effect of these changes is still to increase total VMT. The report states that because only a limited amount of experiments was conducted, it was not possible to generalize the findings to obtain an estimate of the complete relationship between highway supply and VMT.

2.2.3 Loos *et al.*, *The M10 Amsterdam Orbital Motorway*

Loos *et. al.* **[9]** report on the results of an extensive investigation into the impacts of the opening of a new beltway designed to relieve congestion on a key radial tunnel. The Amsterdam Orbital Motorway (A-10) was opened 9/28/90 as the final portion of a beltway (circumferential highway) around Amsterdam. This facility is a freeway and was intended to relieve traffic in the highly congested areas of Amsterdam, which are constrained by a major river/harbor (the North Sea Canal) and an old discontinuous street system through the city. This was a major project that affected many traffic routes, and it made substantial changes in travel times and the relative accessibility of different areas. It was estimated that total travel time delays declined by 20% across all major arterials. The new motorway (freeway) substantially reduced traffic on parallel routes.

Loos used a panel of 12,000 households plus a roadside origin-destination study of 50,000 drivers to evaluate the impacts of the new motorway-- probably the largest survey undertaken for the purpose of studying the impact of a new highway's opening. The four types of demand changes studied included travellers who:

- Chose another route
- Changed their times of departure
- Chose another mode of transport
- Changed their destination, or decide not to travel at all

They concluded that the predominant effects of the new roadway were to change drivers' route and departure time. The facility also affected mode split, destination, and trip frequency, but these effects were very minor compared to the route choice and scheduling effects.

The quantitative impacts of the M10's opening were:

- 25% of all private cars diverted their route as a result of the opening
- Almost 30% of all road users in the target group changed their departure time to some extent. Many of these shifts were relatively small changes limited to within the peak period itself.
- Approximately one percent of all commuters shifted from public transit to the automobile.
- There was little or no change in the destination or frequency of trips. As a result of autonomous developments (population growth, etc.), a increase of two percent could be expected. The actual observed increase of 3% leaves an "induced demand" of one percent of total travel.

2.2.4 Federal Highway Administration, *Highway Statistics*

This is not a study of highway capacity *per se,* but rather a series of selected statistical tabulations relating to highway transportation. Two of these tabulations have been put together in a diagram in Figure 2-1: it shows the correlation between the number of freeway lane-miles[3] per 10,000 population in 22 selected metropolitan areas, and the daily vehicle miles of travel (DVMT) per capita in that metro area.[4] California metro areas are shown as darkened diamonds. The figure shows a clear correlation between capacity (on the horizontal, or x-axis) and vehicle-miles of travel (on the vertical, or y-axis). A straight line has been fitted to the data points, which indicates that each additional lane-mile per 10,000 population correlates with an additional 1.83 daily vehicle miles per capita in the region.

The word *correlation* has been deliberately used here, because correlation and causation are different concepts. It may be that the metropolitan regions that have large highway facilities (per capita) do so *because* of the considerable demands (VMT per capita) placed on them. There is a circular logic that operates here: highway needs (driving) cause highway agencies to build new facilities, the new facilities induce new demand, the demand increases gas tax revenue to the highway agencies, which in turn permits more highways to be build. It is not clear to what extent *building or not building a single facility would induce or suppress vehicle travel* from this figure. Other limitations are that:

- The data on daily VMT are delivered from a relatively small number of samples, and thus may be suspect

- The data are purely cross sectional, and do not reflect changes over time (or for that matter, the period in which the region experienced its formative growth)

- The figure shows only two variables, whereas metropolitan areas are complex and not easily portrayed by averages

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[3] A lane-mile is the length of the facility, times the number of lanes. For example, a 10-mile long freeway having eight lanes would have 80 lane-miles.

[4] Total VMT on all types of highways (not just freeways) was used because it was felt that this would create a more complete picture of travel behavior. Additional freeway usage would likely induce more driving on surface streets (non-freeways), as people access the freeways.

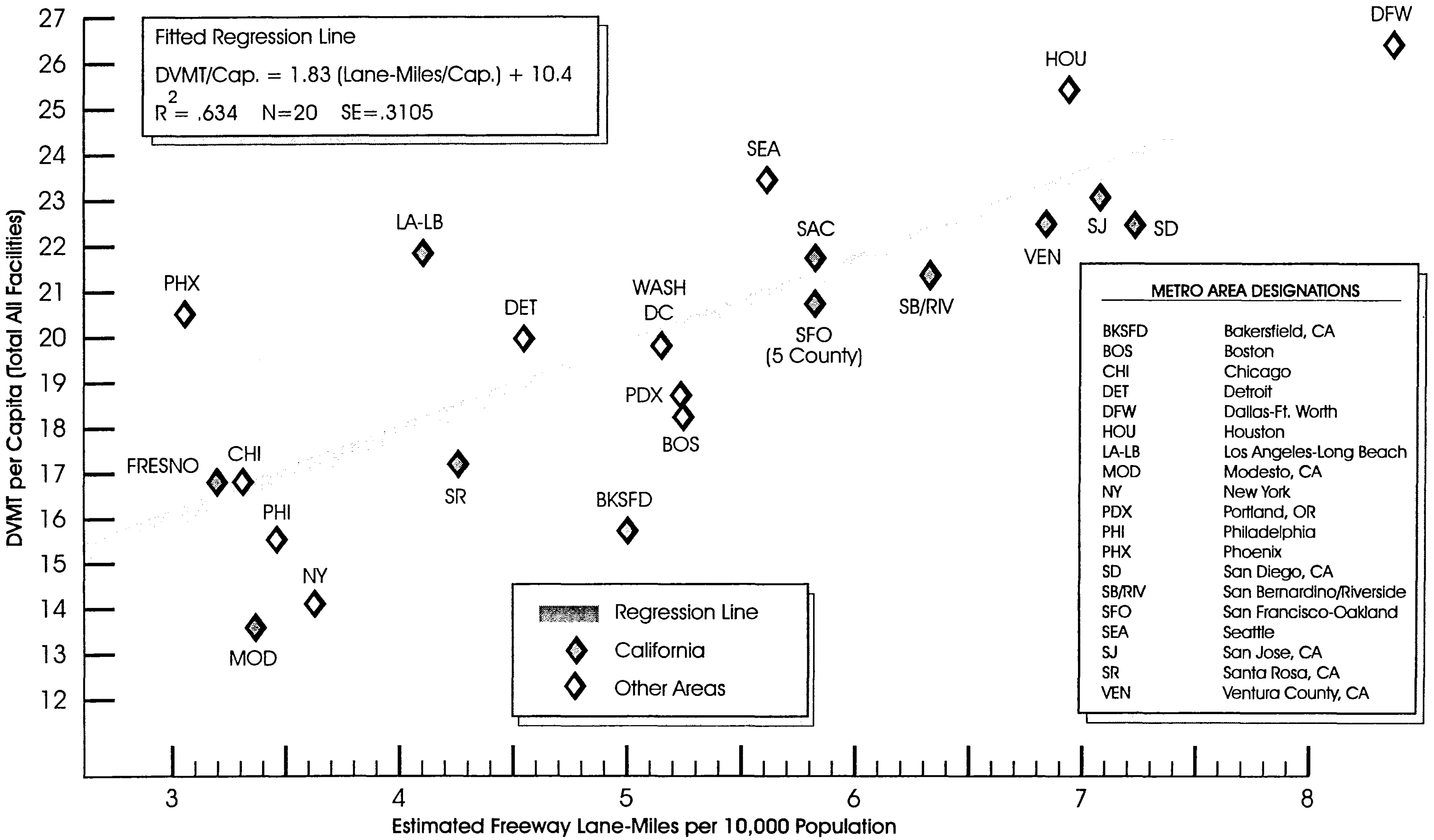

Figure 2-1
Comparison of 1990 Urbanized Area Daily VMT per Capita as a Function of Freeway Lane-Miles/Capita

Source: Federal Highway Administration, Highway Statistics 1990.

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2.3 Studies on the Impacts of Transportation Facility Construction on Land Development

Changes in land use in a highway corridor may be caused in the long term by new highway capacity. Such impacts could include both *redistribution* of activities in the urban area, as well as new activity (i.e., an increase in total activity levels, such as employment or commercial use) in the urban area. Although the distinction is difficult to address, it is clearly an important one, and one that few previous studies pay proper attention to. Several studies were performed in the 1950's and early 1960's of land use impacts of new highways during the formative era of interstate construction. Many of these studies looked at shifts from former "business" routes to the new freeways, and also analyzed impacts of new development around interchanges. Not surprisingly, many of these concluded that motels, gas stations, restaurants and other uses that are now termed "highway commercial" sprang up around the new interchanges. This result is not particularly interesting from a regional perspective, since these uses might have occurred elsewhere in the urban area had the freeway not been built.

More comprehensive studies have been made of new transit construction on the residential location choices of commuters and the land development patterns in the vicinity of the project. Only transit projects are described here, however; many of the conclusions can be extrapolated to highway construction as well.

2.3.1 Dyett *et al.*, *The Land Use and Urban Development Impacts of BART*

Dyett *et al.* **[10]** prepared a study of the land development impacts of the Bay Area Rapid Transit (BART) system, which opened in stages between 1972-74. The report concluded that, after five years of full operation, BART had influenced urban development in the Bay Area, in part by affecting zoning, redevelopment, and other governmental policies. The study concludes that residential and office location were the most influenced, while retailers almost completely disregard BART in their location decisions. BART affected property prices and rents, but the impacts are very small, and in some cases not statistically significant. Regionally, the report concludes that BART did not have a measurable impact on total population or employment growth, but development in BART-served corridors and downtowns (primarily San Francisco, Oakland, and Berkeley) is somewhat greater than it would have been under a "No BART" alternative. This indicates a distributional (i.e., spatial), rather than a growth inducing, impact.

A 1977 survey of employees working in BART-served corridors (within a few miles of stations) indicated that *fewer than ten percent of the respondents said transportation was a factor in selecting their job location.* However, in certain corridors, the influence was much greater. On the residential side, the report concludes that, "BART has had virtually no influence on the initial decisions to move, and has not stimulated moves out of older, urban residential neighborhoods." However, the report notes that BART is a factor, particularly among those with very long commutes. Surveys of movers to Walnut Creek, East Oakland, and the Mission District (San Francisco) indicated that access to BART played a relatively minor role. The top three factors considered by movers to each of these neighborhoods were (in order of importance):

Walnut Creek	Mission District	East Oakland
Neighborhood Character	Access to Public Transit	Easy Access to Work
Housing Type	Neighborhood Character	Housing Type
Easy Access to Work	Availability of Shopping	Schools

A study of Santa Clara County households came up with similar conclusions (Rothblatt, 1975 **[11]**). In that study it was found that the most important variables in residential location were housing cost, housing type or design, neighborhood appearance, and the quality of schools.

The Dyett report was limited by the fact that BART was not in full operation by the time of report completion, and was still suffering from reliability problems. Furthermore, the BART system was an overlay on a relatively well developed highway system, and so did not appreciably affect travel times and accessibility in many corridors. It did provide additional capacity, and it has been argued that in some congested corridors where latent demand existed (particularly the Bay Bridge corridor), BART allowed *more people to travel in the corridor, but did not appreciably reduce travel times or congestion.* Certain hoped-for land use changes, such as high-density residential around suburban stations, or intensified commercial development in downtown Oakland, were not realized for a multiplicity of reasons. These included slow economic growth in the 1970's, public opposition to upzoning and redeveloping certain neighborhoods, urban decay and perception of crime problems in some of the areas served by BART.

The lessons are that:

- A high speed, limited access transportation system is more likely to influence long distance trips than short ones

- Transportation is only one of several factors considered by households in choosing where to live and work

- Impacts of the new capacity will be lessened when it represents a marginal increment to existing capacity, as opposed to greatly altering accessibility or capacity contours in the area.

- Despite a $1.6 billion construction budget (probably about $6 billion in today's dollars), no *regionwide* changes were found in the total population or employment growth of the large, diversified Bay Area economy. This tends to support the hypothesis that transportation facilities *redistribute growth rather than generate it-- a spatial rather than a modal impact.* The lack of economic stimulus to the region may be partly ascribed to the fact that 80% of BART's cost came from locally generated funding sources (property and sales taxes). Injections of external funds (e.g., federal funding) might have provided a greater stimulus to the local economy.

Both the BART and the Rothblatt study suggest that people's residential choice may be made by a series of tiered decisions. Individuals may select residences first by defining an area within an acceptable commuting distance of the current worksite. Within this radius, the final choice is probably more influenced by 'site specific' factors, like neighborhood character, cost, schools, and so forth. This would explain why surveys generally have not indicated congestion or accessibility to be uniformly important choice in residential location.

2.3.2 Knight et al., *The Land Use Impacts of Rapid Transit*

Knight **[12]** analyzed case studies on the land use effects of rail rapid transit systems in North America, including almost a dozen established as well as new systems. He notes that transit had an important impact on land use only when a variety of other complementary factors were present together:

> *These factors include land availability, its ease of assembly, the social and physical characteristics of the area, general economic conditions, community support, and public land use policies. Conversely, when these forces were absent or weak, few land use impacts were found.*

Like the BART Impact Study performed some years later, Knight concludes that there was no evidence that any rapid transit improvements have led to net new regional economic or population growth, and suggests that the growth inducement that was observed was primarily due to shifts from one part of a city to another. Other significant conclusions in his study include:

- The timing of land use impacts seems largely dependent on general economic conditions in the area.
- Local land use policy changes often have been instrumental in facilitating (or inhibiting) the impact of rail transit systems.
- The transit improvement itself has often led to changes in land use policies by the local government, such as upzoning or locating new government buildings near the transit station, reinforcing transit's usefulness.

2.4 Critique of the Published Literature

Several of the facility and corridor-specific studies described here provide detailed demand impact information for specific cases. However, there are many extraneous factors that can affect the results, including the availability of alternative modes and routes in each corridor, the condition of the local economy (growing or stagnant), zoning, and natural constraints to development. These factors not only affect the conclusions but also limit the validity of extending these results to other situations and locations.

Areawide models (derived by correlating VMT growth to highway growth) eliminate the route choice effects by considering entire regions. They are also able to take into account long term land use effects by extending the analysis over several decades. However, they focus on vehicle rather than person trips, and so consequently ignore mode choice impacts.

The areawide studies also suffer from the limitation that they use single relatively simple measures of capacity increases (such as lane-miles) that are insensitive to the potentially significant different demand effects that would occur if the same investment is made in the center of the region versus the fringes. Some of the land use forecasting models, discussed later in this report, have attempted to deal with this problem. This limitation could be removed if more detailed data were available.

One important conclusion is repeated consistently throughout the literature: the elasticity of demand is nearly always less than one, or as economists would say, inelastic. That is, considering the whole urban area, a X% decrease in travel time (or increase in average speed) will cause less than an X% increase in the number of trips made. The implication of this conclusion is significant: if one doubles the number of lanes on a freeway, or the number of lane-miles in a region, *the amount of VMT will increase, but by less than doubling.* This seemingly trivial conclusion is actually quite important, since if it were not true, it is possible that increasing capacity could worsen congestion in the long run. This conclusion refutes the most polar opinions held on the topic of induced demand: new capacity will neither help solve congestion as much as some proponents of highway widening claim, nor will it induce as much new traffic as some opponents of new capacity claim. Clearly, one of the most difficult problems in understanding the demand inducing effects of new capacity is the fact that there are many different effects and they are highly interrelated. The accuracy of travel forecasts would benefit if they considered some increment of new travel induced by the new capacity.

3. Results of Travel Behavior Survey

3.1 Introduction

The major difficulty with past case studies of new highway facilities has been their failure to isolate the relative importance and magnitude of the various effects of these facilities on traveler behavior. Many of these effects (such as route choice and mode choice) are already considered in current travel behavior models used in California's larger metro areas. Other effects (such as trip start time, and trip generation) are not well represented in current travel behavior models. The case studies therefore do not allow us to determine the relative importance of the behavioral effects that are currently well modeled and those effects that are excluded from most current travel demand models.

A behavioral survey where individual travelers are interviewed as to their travel habits and characteristics allows us to develop a behavioral model of peoples responses to new highway capacity and compare this model to the conventional travel forecasting models used in current practice.

3.2 Survey Objective

The behavioral survey was developed and administered to fill in the missing information from the case studies on the relative importance of the different effects of new highway capacity on travel behavior. Each potential effect (mode, time, destination, trip generation) would be identified and quantified for the purpose of determining its relative importance in estimating the total demand effects of new highway capacity.

3.3 Selection of Survey Approach

There are two general approaches to conducting behavioral surveys: stated preference (SP) and revealed preference (RP). A stated preference survey poses various situations to the interview subject and asks them how they think they would respond to the given situation. A revealed preference survey relies upon the interviewee revealing their actual response to different conditions existing in the field. A "before and after" survey is one type of RP survey. RP surveys can test only for the conditions that exist in the field, while an SP survey can look at options that don't yet exist in the field.

RP surveys have traditionally been used to calibrate travel forecasting models. RP surveys provide information on the actual, discrete choices made by individuals in the face of two or more options. A "before and after" study comparing travel diary information before and after the opening of a new freeway would be an example of the RP approach: the change in the number of trips per person would indicate the impact of opening the new freeway.

There are, however, several weaknesses in applying RP behavioral surveys to the problem of estimating the behavioral effects of new highway facilities. The critical weaknesses are the difficulty in avoiding bias in the selection of the survey sample and accounting for persons moving into and out of the presumed "impact" area of the new facility. The time frame of this study also did not permit an adequate amount of time to develop the survey, administer the survey before a new highway facility was opened, and to administer the "after" portion of the survey after people had become accustomed to the new facility.

SP surveys tend to be longer than RP surveys because the "hypothetical" situation must be carefully posed to the interviewee. However an SP survey requires only a pre-test and then a full-scale execution while an RP survey would have to be administered in two waves to catch the "before and after" effect of a capacity increase.

It is natural to feel that greater faith should be put in actual decisions rather than data on what respondents say they would do faced with hypothetical choices. But several studies (Ben-Akiva **[13]**, Fowkes **[14]**, Bates **[15]**) have analyzed parallel SP and RP data sets, and found the results comparable from the two survey techniques. In fact, considering cost and other factors, Fowkes states flatly that "stated preference clearly outperformed the others [survey techniques]." SP surveys are now commonly used and accepted in Britain for transport studies.

Once the decision was made to go to a stated preference approach the next decision was how to administer the survey. SP surveys have usually been conducted over the phone with the assistance of a computer to interactively frame the questions in response to the prior responses of the interviewee.

The survey also embodied concepts from the developing field of activity analysis. The basic concept of the activity based travel model is that everyone has exactly 24 hours in a day, and 168 hours in a week, to allocate among various activities--including travel. For the person who works eight hours a day, and sleeps eight hours a day, this leaves only eight hours for commuting, handling errands, household and family chores, recreation, and so forth. The allocation of time is not a simple process, since each person faces a set of constraints that must be met: a worker might have to be at his/her job at exactly 8 AM, or might need to pick up a child from Little League at between 4:00 and 4:15 PM. Within the survey instrument developed, people were asked about all of the previous day's activities, and then asked to relate how their behavior would change with changes in travel time to that reference day.

3.4 Development of Survey Instrument

The CATI (computer assisted telephone interview) survey allowed interviewers to phrase the questions in response to the particular situation and behavior of each respondent. For example, people who had stayed home the previous day were not asked about how they would have reacted to a savings in travel time on the previous day. The survey instrument (see Appendix) was divided into 6 sections:

Section "A" provides information on the household's demographics. This information is necessary for determining factors influencing trip generation and the respondent's trip behavior.

Section "B" provides information on the attitudes and perceptions of the respondent towards transportation issues. These questions were not directly related to the survey objective but they were included to "warm-up" the respondents and to allow future cross checking of responses against these general opinions.

Section "C" provides the baseline information on the survey respondent's travel behavior on the previous day.

Section "D" takes the respondent through the previous day's trips and asks how the respondent would respond to time savings on each trip, and to total travel time savings for the entire day.

The key to obtaining reliable results from a stated preference survey is to frame the questions in as realistic a manner as possible. For this reason it was crucial that travel time savings questions be limited to a realistic range of potential travel time savings and that these savings be focussed on specific trips made the day before by each individual. For these reasons the travel time savings was limited to a maximum of 50% of the normal travel time for each trip. The minimum savings asked, five minutes, was set to the smallest unit of measure likely to be perceived by the respondents. Thus trips of under ten minutes duration (about 41% of the trips in the previous day's sample) were excluded from the travel time savings questions.

All time savings questions were rounded to the nearest five minutes since this was believed to be the smallest unit of measure perceived by travelers. The survey results generally confirmed that people perceive their travel time in units of five and 15 minutes.

Section "E" asks the same questions as Section "D" but for the reverse situation where traffic congestion increases travel time. The intent was to assess whether time savings are perceived by the traveler in the same manner as time losses. The maximum additional travel time asked of each individual for each trip was limited to 100% of the normal trip time so as to keep the question within the bounds of most individual's experience. The minimum added time asked was set at five minutes. Section "F" is really a continuation of Section "A", but it has been placed last since income questions are often the most sensitive questions in a survey. The income question was placed last to avoid losing survey respondents early in the survey.

The survey instrument was pre-tested on 30 households and the results reviewed by the Technical Advisory Committee. The original survey instrument required about one hour to administer to each respondent, which was tiring to both the interviewer and the respondent. This resulted in respondent attrition. The TAC and consultant team reduced the content of the survey instrument by about 50% in order to keep the time to administer the survey to under 20 minutes.

A copy of the complete survey questionnaire is included in Appendix A. Survey methodology and recommendations for future improvements are in Appendix B.

3.5 Survey Results

A total of 676 individuals over the age of 16 were interviewed in 676 households. They collectively reported a total of 2,182 trips the previous day.

3.5.1 Household Characteristics

The characteristics of the households surveyed in San Diego and San Francisco metropolitan areas are generally consistent with similar data obtained from the 1990 U.S. Census for these area. There were an average of 2.67 persons per household and 2.03 autos per household in the survey. About 63% of the surveyed households were single family homes. Table 1 provides a summary of the surveyed household characteristics.

3.5.2 Respondent Characteristics

The characteristics of the respondents showed a slight bias toward older individuals (mean age of 43 years for respondents vs. 35 years for the households) and toward females (55% female respondents). This is shown in comparing Tables 1 and 2. The older age bias was due to the decision to interview only people old enough to drive. The sex bias was controlled as much as possible by initially asking for a target individual in the household. However, the interviewer was instructed to accept the person that answers the phone if the target individual is not available in order to reduce the refusal rate which had been quite high in the pre-test.

The respondents were split almost equally between high school and college graduates. Less than four percent did not drive and 57% were employed full time.

3.5.3 Travel Habits

The travelling characteristics of the respondents are shown in Table 3. Approximately 9% of the respondents stayed home the previous day. They made an average of 3.3 trips per person with an average trip length of 20 minutes and 11.3 miles. Ninety-two percent made their trips by car (either alone or in a carpool).

Each respondent spent on the average a total of 64 minutes travelling the previous day.

The results show a high proportion of short trips. Forty-one percent of the trips are under 10 minutes in length and 49% are under five miles in length. Less than 40% of the trips are longer than 15 minutes (see Figure 3-1). These short distance trips are unlikely to be greatly affected by changes in highway capacity, since the time savings involved in new highway capacity can only reduce the travel time by a few minutes at most.

The results also demonstrate that respondents tend to perceive travel time in units of five and 15 minutes. There are sharp spikes in the number of respondents reporting trips of 5 minute, 10 minute, and 15 minute duration compared to the number of responses for travel times in between these values. Respondents generally reported travel times to the nearest 15 minutes for trips greater than 30 minutes in length.

The average auto occupancy for all trips was 1.48 persons per car. Respondents showed a strong preference toward carpooling with fellow household members. Household carpools outnumbered other carpools by a ratio of 3 to 1.

3.5.4 Response to Travel Time Changes

The respondents showed a high degree of resistance to changes in travel times. Over 35% of the time they would make no change in their travel habits even when offered an increase or decrease of 15 minutes in their trip travel time. Another 20% to 40% would simply arrive earlier or later and make no change to the departure time to compensate for the effect of the time increase or decrease. The respondents indicated that about 10% to 15% of the time they would reschedule their departure time to compensate for or take advantage of the travel time increase or decrease.

The result of this is that 90% to 95% of the trips would be unchanged or would have schedule changes in response to travel time increases and reductions of 15 minutes or less. The results are shown in Tables 2 and 3.

A time savings of five minutes would generate extra stops for about three percent of the trips where this time savings was offered. This percentage increased to five percent when 15 minute time savings were offered. The average across all time savings offered was three percent. Higher time increases and decreases had a greater effect on traveler responses than lower amounts of time changes.

The respondents tended to react slightly more strongly to increases in travel time than to decreases (see Figure 3-2). When faced with a travel time increase, respondents would try to adapt by changing mode, destination, and route for a higher percentage of the trips than if they were offered an equal amount of time decrease.

Table 1 Household Characteristics of Survey Respondents

Item	Results
Area	San Francisco - 52% San Diego - 48%
Average Persons per household	2.67
Average Age of all persons in household	35.0 years 19% under 16 years old 6% over 70 years old
Sex Distribution of Household	50% male 50% female
Structure Type	63% single family home 37% apartment, condo, other
Ownership	61% own 39% rent
Auto Ownership	2.03 cars per household (3% of households own no cars)
Motorcycle Ownership	0.12 motorcycles per household (91% of households own no motorcycle)
Bicyclists per household	1.17 per household (42% of households have no bike riders)
Length of Time at Same Address	50% have lived less than 4 years at same address.
Median household Income	Between $30,000 and $50,000 per year

Source: Dowling Associates/Air Resources Board travel survey, 1994.

Table 2 Respondent Characteristics

Item	Results
Sex	Male - 45% Female - 55%
Average Age	43.2 years less than 1% under 16 years old* 8% over 70 years old
Employed	Full-time = 57% Part-time = 10% Student = 6%
Drivers License	Yes - 96% No - 4%
Highest Education Level Attained	College Graduate: 46% High School Graduate: 51%
Opinion: Is congestion a problem?	Agree - 68% Disagree - 30% No Opinion - 2%

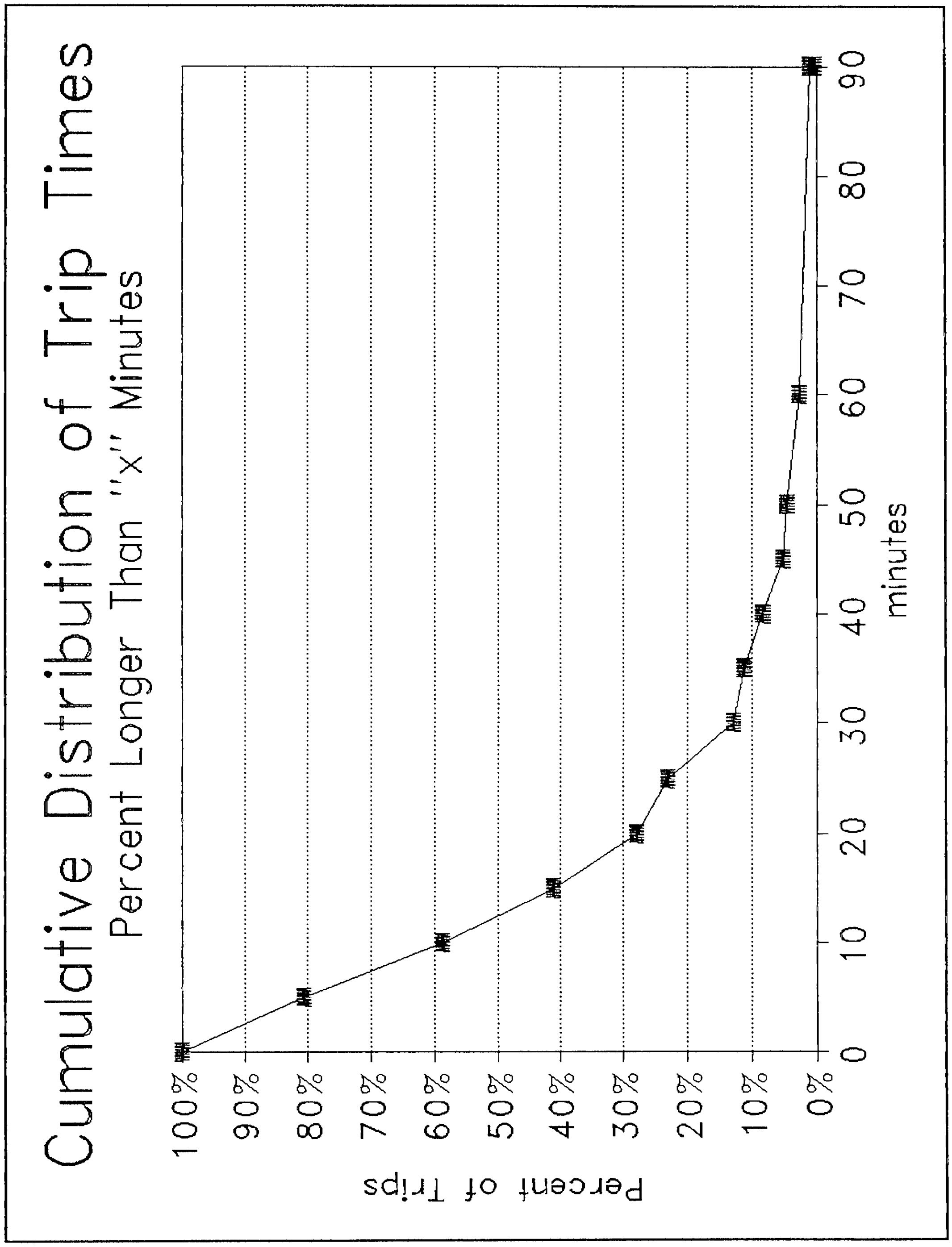
Source: Dowling Associates/Air Resources Board travel survey, 1994.

* This result is not surprising, since the survey interviewers asked to speak to someone over age 16.

Table 3 Travel Characteristics of Respondents		
Item	Results	
Trips Made Yesterday	Range = 0 to 15 person-trips Mean = 3.23 person-trips Nine percent of individuals made no trips on the prior day.	
Trip Length (time)	Range = 0 to 6 hours Mean = 20.0 minutes Median = 14.5 minutes 41% of all trips are 10 minutes or less	
Trip Length (miles)	Range = 0 to 300 miles Mean = 11.3 miles Median = 6.0 miles 92% of all trips are 25 miles or less	
Trip Purposes	Commute to work	31%
	School	4%
	Social	11%
	Shopping	16%
	Personal business/errands	16%
	Eat	7%
	Serve passenger	11%
	Other	4%
Mode of Travel	Drive Alone	62%
	Carpool with household members	22%
	Carpool with others	8%
	Public Transit	3%
	Walk	4%
	Bicycle	1%

Source: Dowling Associates/Air Resources Board travel survey, 1994.

Figure 3-1 Cumulative Distribution of Travel Times



Source: Dowling Associates/Air Resources Board travel survey, 1994.

Table 4 Responses of Travelers to Travel Time Savings for Each Trip

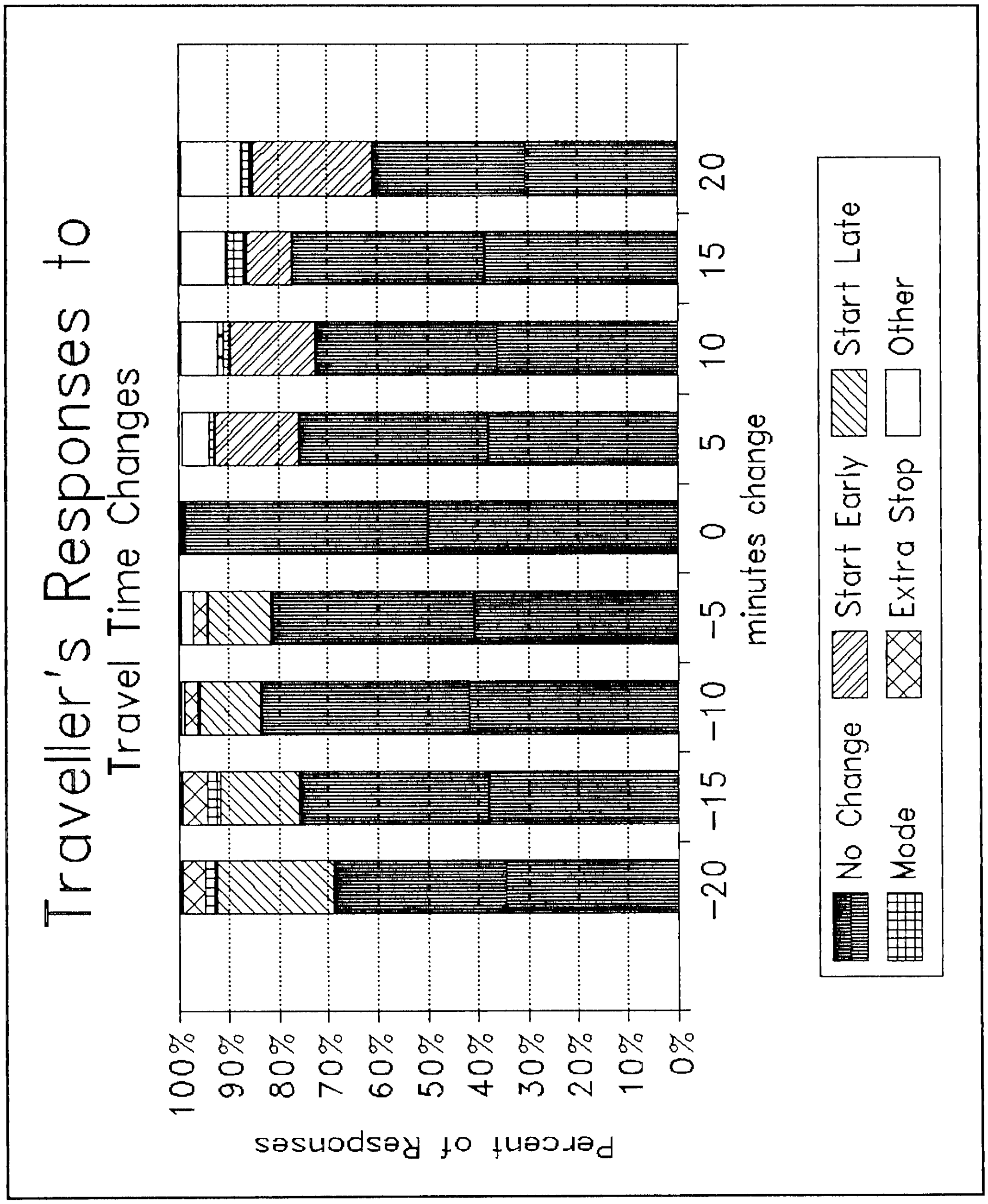
	Travel Time Savings Asked (minutes)				
Response	5	10	15	20+	All
No Change	46.5%	49.6%	35.1%	38.1%	46.5%
Arrive Earlier	34.9%	33.9%	40.5%	31.0%	34.6%
Leave Later	12.9%	12.5%	16.2%	23.8%	13.5%
Change Mode	0.4%	0.4%	2.7%	2.4%	0.6%
Change Destination	0.9%				0.5%
Make Extra Stop	2.9%	2.8%	5.4%	4.8%	3.1%
Other	1.5%	0.8%			1.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0

Table 5 Responses of Travelers to Travel Time Increases for Each Trip

	Travel Time Increases Asked (minutes)				
Response	5	10	15	20+	All
No Change	53.5%	41.3%	38.6%	24.4%	45.7%
Arrive Later	22.1%	31.0%	38.6%	36.6%	27.8%
Leave Earlier	17.3%	17.6%	9.1%	24.4%	17.4%
Change Mode	1.2%	1.5%	4.5%	2.4%	1.6%
Change Destination	1.0%	0.4%	2.3%		0.7%
Make Extra Stop	0.2%	1.3%			0.7%
Other	4.6%	6.9%	6.8%	12.2%	6.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dowling Associates/Air Resources Board travel survey, 1994.

Figure 3-2 Response of Travelers to Travel Time Changes



Source: Dowling Associates/Air Resources Board travel survey, 1994

4. Review of California and Other Case Studies

4.1 Introduction

Three case study sites were chosen from California to examine short term impacts of new highway capacity. The hope was to validate the conclusions from the case studies performed by others (Chapter 2) and indicated by the household survey (Chapter 3). There was also a desire to include a case study of a high-occupancy vehicle (carpool) lane capacity addition. Most other case studies have ignored this type of project.

In order to make valid comparisons, it was necessary to select capacity expansion projects that met the following criteria:

- Projects opened relatively recently
- New freeway or widening in an urban area
- Congested travel conditions prior to widening
- Minimal paralleling arterials that would form good alternates (this was done in order to assure that the measure impact was not made up of trips diverted from one route to another)
- Before and after count data available at hourly intervals

It was surprisingly difficult to find project that could fulfill all five selection criteria. It initially appeared that three projects would meet the criteria:

- Route 78 (San Marcos Freeway) in northern San Diego County
- Route 85 (South Valley Freeway) in southern Santa Clara County
- US 101 (Redwood Freeway) in San Rafael, Marin County

Subsequent to picking these projects, it was found that some of the traffic count data were not very good, because counts had been conducted at irregular intervals and at different seasons of the year. In the case of the Bay Area, the problem was compounded when it was discovered that all historic hourly counts were destroyed when the Caltrans District 4 moved its offices to Oakland in 1992.

These specific projects do represent three different kinds of capacity expansion: widening an existing freeway with a mixed-flow lane, an entirely new freeway where none existed before, and a high-occupancy vehicle (HOV) lane added to an existing freeway. The first two cases represent capacity additions in locations where rapid growth has been occurring in the past decade; the last (US 101) represents a relatively stable residential environment, with some new office construction occurring through 1990 in the area served by this freeway.

Because the California case studies did not provide as much useful information as hoped, they were supplemented by brief case studies of Canadian experience (where relatively few high performance urban highways have been built), and with an assessment of the impacts of the 1989 Loma Prieta earthquake, in which substantial *reductions* in capacity occurred.

4.2 California Case Studies

4.2.1 Route 78 (San Marcos Freeway) - San Diego County

Area Description

State Route 78 (SR 78) is an east-west freeway located in northern San Diego County, as shown in Figure 4-1. San Diego County's current population is more than 2.6 million. The four cities along this route-- Oceanside, Vista, San Marcos, and Escondido, have a combined population of approximately 370,000. San Diego County has been among the fastest growing counties in the state, with an increase of 34% between the 1980 and 1990 censuses (compared to a statewide growth of 25.7%). Route 78 was constructed as a four-lane freeway in the 1960's, but rapid growth in the past 10-15 years has created significant congestion along it. There is still significant undeveloped land in the corridor which is suitable for urbanization in the future.

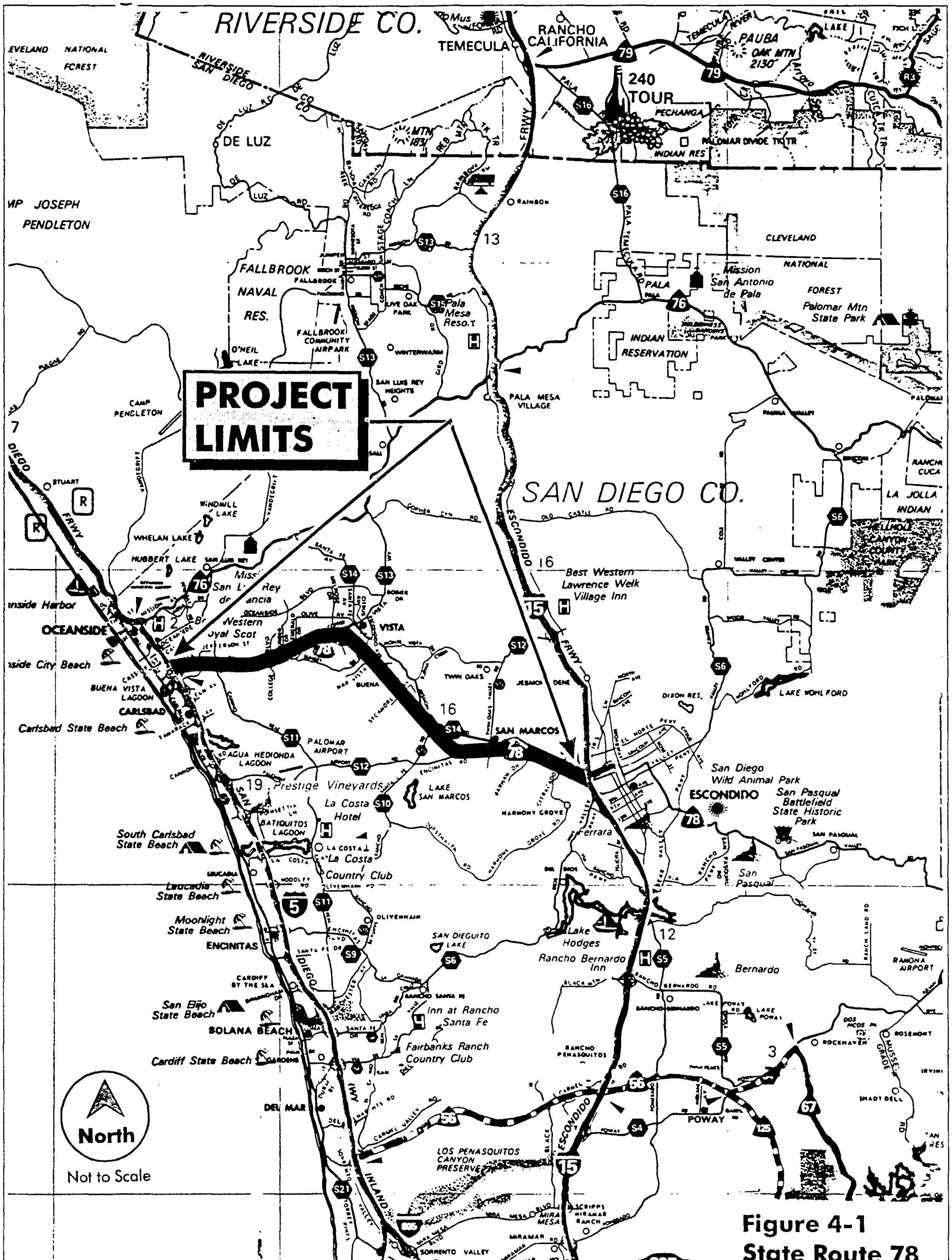


Figure 4-1
State Route 78 and Vicinity

Description of the Highway and Expansion Project

SR 78 provides a "bridge" between two freeways: I-5 in Oceanside and I-15 in Escondido. Prior to the widening project, this was a four-lane freeway, approximately 17 miles long, with a short portion near I-5 having six lanes. Historically, this facility was the product of transportation and land use planners' expectations in the 1950's and 60's that most growth in San Diego County would occur in the then-existing coastal cities. The trend toward inland development had not been foreseen, leaving this facility with inadequate capacity to meet the demands placed on it by rapid population growth. While most of this freeway had operated acceptably (level of service "D" or better during peak hours, see sidebar) as recently as 1984, in recent years several locations had deteriorated to level of service "E" and "F".[5] In the late 1980's, San Diegans voted to increase their sales tax by 1/2 cent in order to finance a number of transportation improvements ("TransNet"), of which widening SR 78 was one project.

Completion of the widening occurred in stages between late 1993 and early 1994, increasing the freeway's capacity by more than 50%. Fortunately, traffic counts were available from Caltrans District 11, which were done soon after the completion of the widening. Because the widening was staged over a number of years, traffic counts during 1992 and early 1993 at some locations were not considered valid, even though available. Besides the impact on congestion of construction activities, road construction often damages or impairs traffic counting equipment, rendering the result suspect.

Average daily traffic volume (ADT) on SR 78 range from 95,000 to 115,000 ADT today. There is some bus transit service parallel to the freeway, but for the most part, service frequencies are not very good (30-60 minutes between buses), nor are travel times very competitive with the auto. There are no good alternatives to the freeway for most travellers going more than a few miles; the few parallel arterials to SR 78 are generally discontinuous.

[5] Source: San Diego Association of Governments (SANDAG), "Info," November-December 1988.

Before v. After Capacity Expansion Traffic Volumes

Figure 4-2 shows the daily traffic volumes at two locations, in both directions, from 1981 thru 1993. Years with zero count indicate no count was taken that year. The locations were about 1.5 miles east of I-5, and the other immediately prior to (west of) I-15. These are the two highest volume locations on SR 78. Prior to widening, the location near I-5 had been showing increases of 3-7,000 ADT per year, and the I-15 location had been increasing at 3-9,000 ADT per year. Between 1991 and 1993, the growth rate at the former location was 6,500 ADT per year, and at the latter, 2,500 per year.

The before and after improvement hourly traffic flows are plotted on the same figure; overall, the after condition shows a total increase in volume of more than 14%. Changes in peak hour flows near the mid-section of the Route 78 freeway are shown in Figure 4-2 (counts were taken near Santa Fe Road). Although this area experiences lower volumes than near the interstates, there was

Highway Level of Service (LOS)

Highway level of service is a qualitative measure describing operational conditions within a traffic stream, or their perception by motorists and/or passengers. LOS considers speed and travel time, freedom to maneuver, comfort and convenience, and safety.

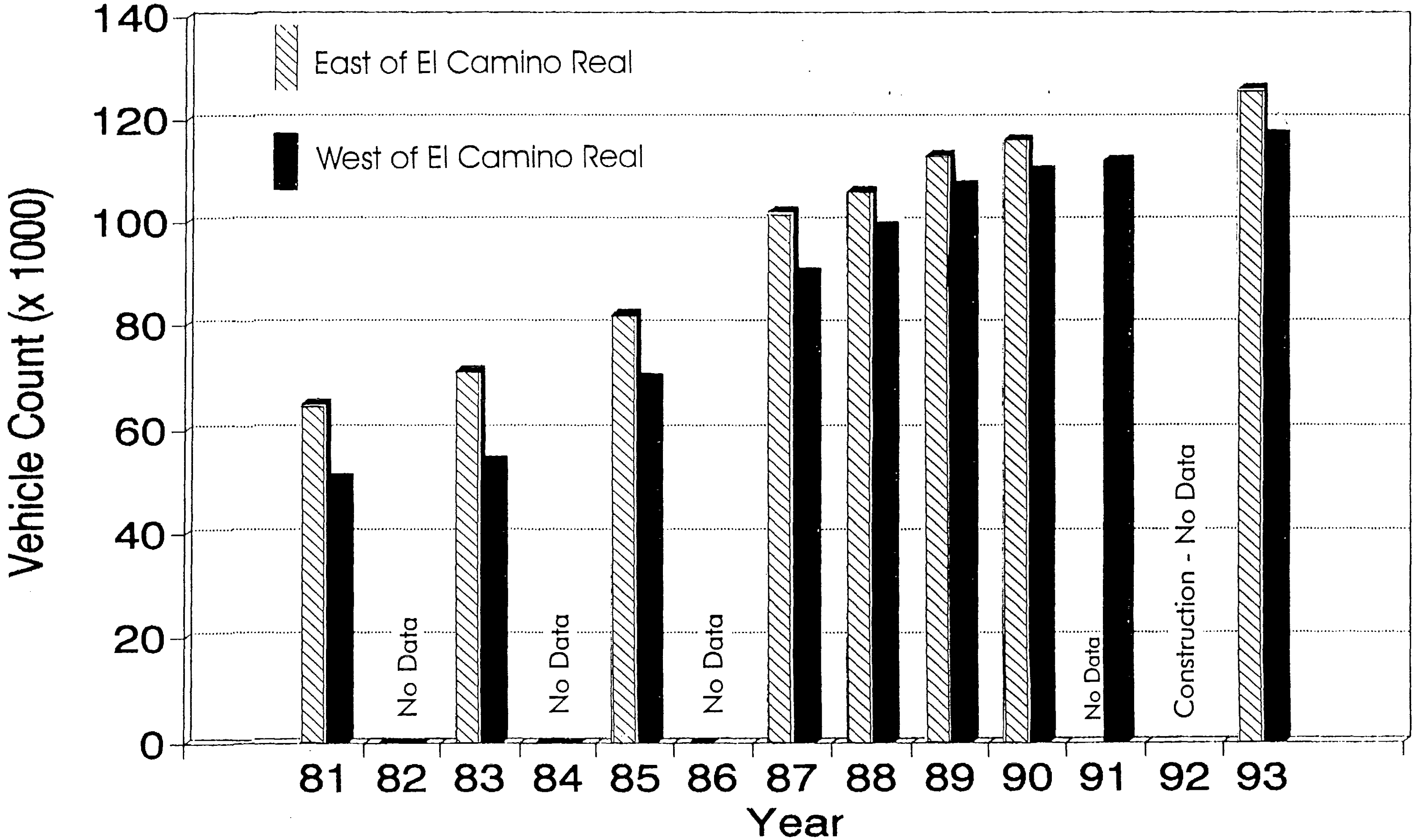
There are six LOS "grades", ranging from "A" (best conditions, i.e., free-flow of traffic) to "F" (worst conditions, stop-and-go "jammed" traffic).

For modern freeways, a LOS of "A" generally equates to average travel speeds 55-60 MPH. The other LOS designations are:

B 57-60 MPH
C 54-56 MPH
D 46-53 MPH
E 30-45 MPH
F Under 30 MPH

These speeds are only approximate, and LOS is usually determined from the density of traffic, i.e., how many vehicles there are per lane-mile of highway.

Figure 4-2
Route 78 Average Weekday Traffic Trends
San Diego County Between I-5 & I-15



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seasonably comparable data available at this location.[6] Although individual days were chosen, both are for Thursdays (August 15, 1991 and June 24, 1993).

The increases are not distributed evenly over the day: as is expected from theory, the peak hours (6-9 AM and 2-6 PM) show the largest relative increases; e.g., the peak hour 7-8 AM volume (which is the highest registered at this location) increased by more than 22%. Very early morning volumes also increased by large relative amounts, although this could reflect a congestion-coping response of those who use SR 78 to access I-15; I-15 has become increasingly congested, with the peaks starting earlier and lasting longer in recent years.

Conclusions

Key conclusions from the analysis are:

- The increase in *daily* traffic volume after the widening project was consistent with the magnitude of increases that had been occurring prior to it.
- Traffic volume increases were concentrated in the morning and afternoon peak periods, when congestion was worst, indicating that the primary impact of the project was on the choice of time trips were made (i.e., trip scheduling).

Beginning in 1990, California faced an economic downturn from which even the fast-growing San Diego County was not immune. Between 1990, countywide employment decreased by four percent, with a 4.7% decrease in the North County.[7] Although employment in the SR 78 corridor is less defense oriented than in many other parts of San Diego, there are undoubtedly persons commuting to defense-related jobs who live in this corridor (or whose job is a secondary effect of defense expenditure). Because of this, a comparison between 1991 and 1993 should be made with great caution.

[6] The other locations would have required comparing December to August volumes. There are several reasons to shun such a comparison; one in particular is that SR 78 takes inland residents to the beach, and may serve the recreational purposes of other trips.

[7] Between 1990 and 1992, employment in the North County (the boundaries of which conform fairly well to the origin and destination of most trips made on SR 78) declined from 260,400 jobs, to 248,300. Source: San Diego Association of Governments (SANDAG) *INFO*, March-April 1994, Table 3, page 4.

The results available in this short term analysis do not indicate any great increase in weekday traffic volumes due to the new capacity. Although traffic volumes continued to grow in the "after improvement" period, the increases were well within the expected range of results, given the increases in the period immediately prior to the improvement (1987-1990). Thus, the available evidence does not point to any statistically significant induced demand effect, given the "background" increase in development and traffic in the area. Of course, it is arguable that the growth rate might have flattened due to congestion, but this is more likely to be felt in terms of the hourly volumes.

The changes in the hourly volumes appear more in line with the behavioral changes that would be expected from travel theory. These counts show that the capacity increases, by relieving bottlenecks along SR 78, allowed more vehicles to travel during when, presumably, they wanted to travel: namely, during the "peak of the peak" hours. It would be desirable to have 15 minute time resolution to identify even smaller shifts, but that information was not available.

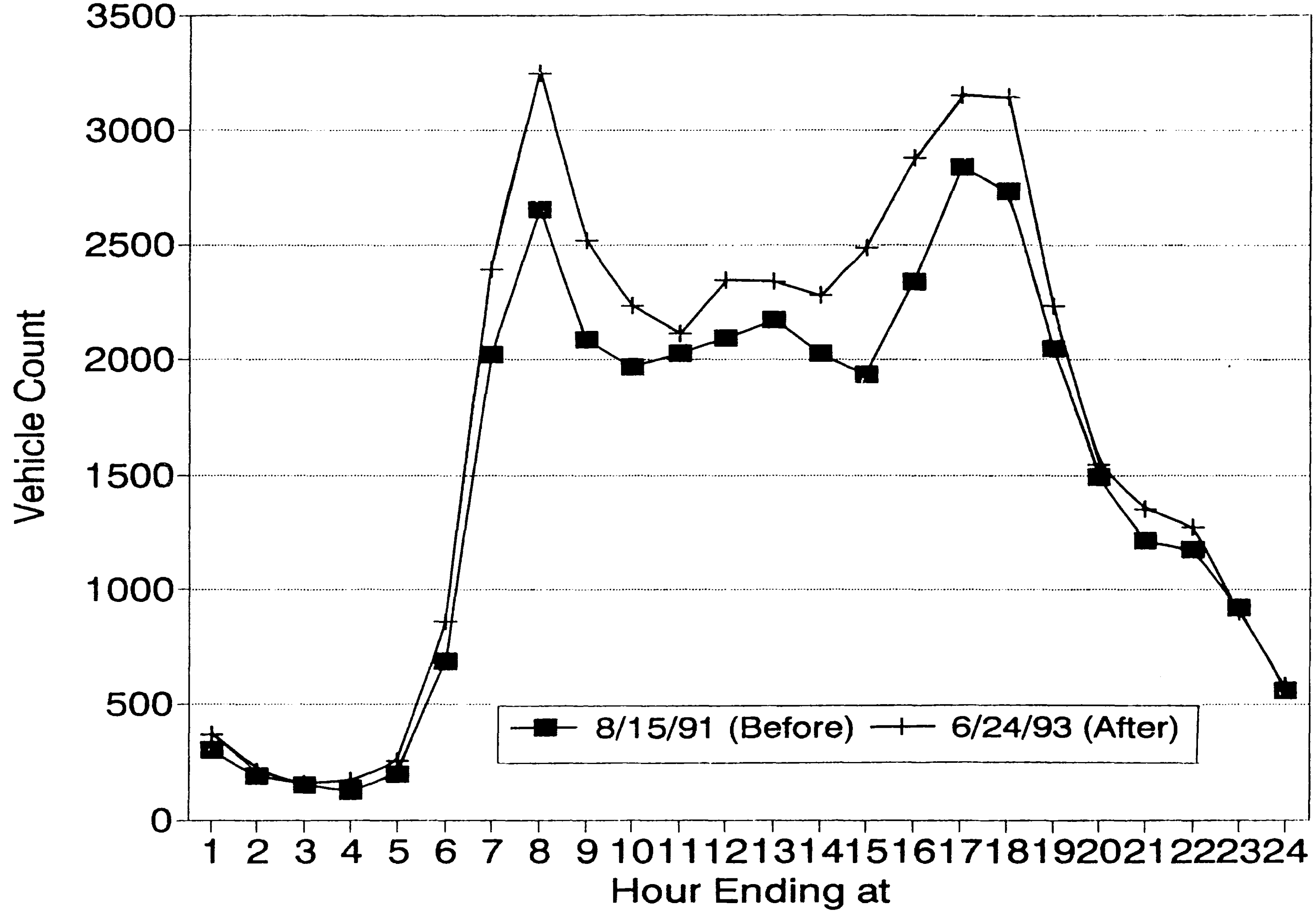
4.2.2 Route 85 (South Valley Freeway) - Santa Clara County

Area Description

This portion of Route 85 is located in the fast-growing Coyote Valley portion of southern Santa Clara County. The Association of Bay Area Governments (ABAG) publishes job breakdowns only for the City of San Jose as a whole, but the employment of the city increased by more than 15% in just the five years between 1985 and 1990 (since that time, employment is believed to be relatively flat). The area served by this freeway also has large tracts of undeveloped land, although it today has considerable population and employment. IBM and other high-tech manufacturing businesses are located in this area, and others have expressed interest in expanding in this area, which is generally less congested than the Silicon Valley 15 miles to the northwest, and where land is available and real estate costs are lower (see Figure 4-4 for an orientation map).

From a theoretical standpoint, this is the kind of area in which it is most likely that major new transportation improvements could stimulate land use changes (redistribution or new uses). This area is targeted within the city's general plan for major growth between now and the year 2010, with considerable tracts of agricultural or fallow land being converted to urban uses.

Figure 4-3
Route 78 Hourly Traffic Flows
Eastbound at Rancho Santa Fe Road



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Description of the Highway and the Expansion Project

Approximately 5.5 miles of the SR 85 freeway opened on October 19, 1993, from US 101 on the south, to the Almaden Expressway to the north and west. Ultimately, about 20 miles of new freeway construction will be involved, connecting 101 in south Santa Clara County with Routes 17 and 280 in the central section of the county. This will create a southerly and western bypass around central San Jose, and is intended both to serve existing and new development in this area, as well as relieve congestion through the developed portions of San Jose and the central Santa Clara Valley.

SR 85 is currently four mixed-flow lanes, and ultimately two HOV lanes will be added, for a total of six lanes. As of April 1994, some of the freeway-to-freeway interchange ramps between 85 and 101 have not been completed.

Before and After Capacity Expansion Traffic Volumes

Traffic counts were made in March 1994. Current average weekday counts south of Blossom Hill Road (at roughly the freeway's mid-section, about 3.9 miles northwest of US 101), the volume is currently 30,650 ADT, which is low for a four lane freeway. Four lane freeways can typically carry at least 50,000 ADT without congestion. However, other highways in this area are relatively congested; US 101 in this area carries 150,000 AADT[8] in this area on six lanes; Route 82 (Monterey Highway) carries 25,000-35,000 AADT and is a surface street.

There are no comparable before and after counts for Route 85 itself, because this was an entirely new facility. Only one comparable traffic count could be found in the vicinity for the before-and-after situation on nearby roads that might have been serving as parallel routes. Southbound PM peak (5-6 PM) volumes were available on Santa Teresa Blvd. at Blossom Hill Road on the north leg. The March '92 count indicated 830 vehicles per hour (VPH), and the February '94 count indicated 1,070 VPH, a 29% increase. Some 1991 and 1992 counts were made on Blossom Hill Road and on Santa Teresa Blvd., however, these locations have not been subsequently counted.

[8] AADT is annual average daily traffic, including weekends. Typically, the ADT on a roadway is for a weekday, and in urban areas is typically somewhat higher than the AADT.

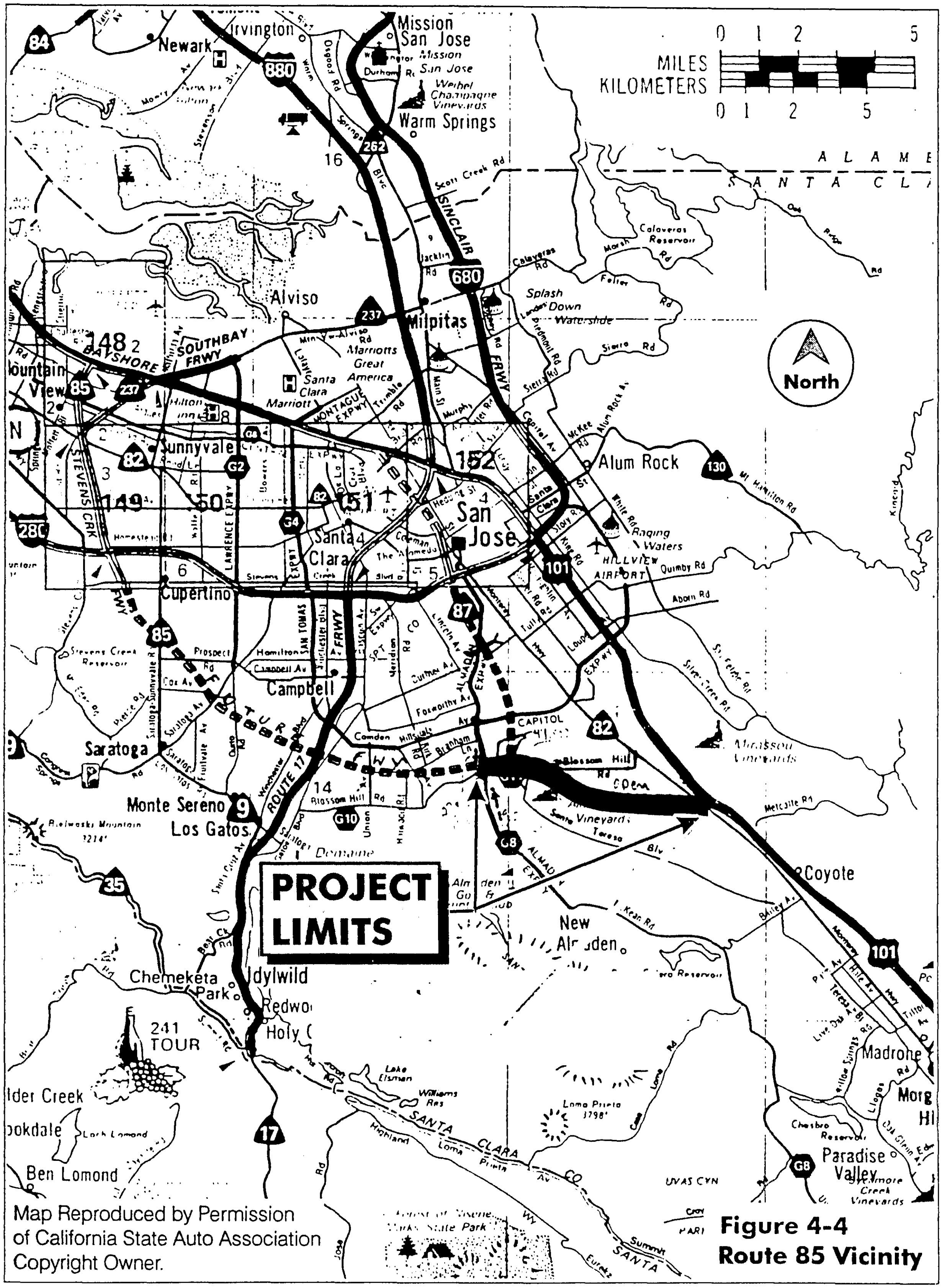

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Figure 4-4
Route 85 Vicinity

Conclusions

Volumes clearly grew substantially in a short period of time at one leg of the count intersection, although the intersection of Blossom Hill/Santa Teresa is about one-half mile south of the Route 85 freeway interchange, and traffic turning from Blossom Hill Road onto the freeway would be attracted to this street segment as a result of the freeway opening. Good counts were not available on Blossom Hill Road in order to assess this change in volume. Again, this points to the difficulty of making valid comparisons of the effects of a new facility opening. Changes in land use patterns in the next 5-10 years may make for an interesting case study.

4.2.3 US 101 High Occupancy Vehicle Lanes - San Rafael (Marin County)

Area Description

Marin is a prosperous county of 230,000 people located north of San Francisco. Although originally a bedroom suburb, in the 1980's it began to develop a significant job and retail base of its own. The City of San Rafael is the largest city in the county, and is located in the central portion of the county. Between 1980 and 1990, its estimated total jobs grew from 33,350 to 41,300.[9] The county's total jobs increased by more than 25,000 (almost a third) during this period.

This corridor is served by excellent commuter bus and several ferry services to San Francisco are operated by Golden Gate Transit; during peak periods, there is a bus every minute going over the summit of Puerto Suello hill in San Rafael. Most of these services are oriented toward taking commuters to job concentrations in the northeastern quadrant of San Francisco.

Description of the Highway and Expansion Project

This project is located in central Marin County, about 17 miles north of San Francisco (see Figure 4-5). US 101 is the only continuous freeway through this county, although a short segment of I-580 also connects San Rafael to the East Bay via the Richmond-San Rafael bridge. The Puerto Suello Hill area just north of

[9] Source: ABAG *Projections '92 Recession Update* (Association of Bay Area Governments, December 1992).

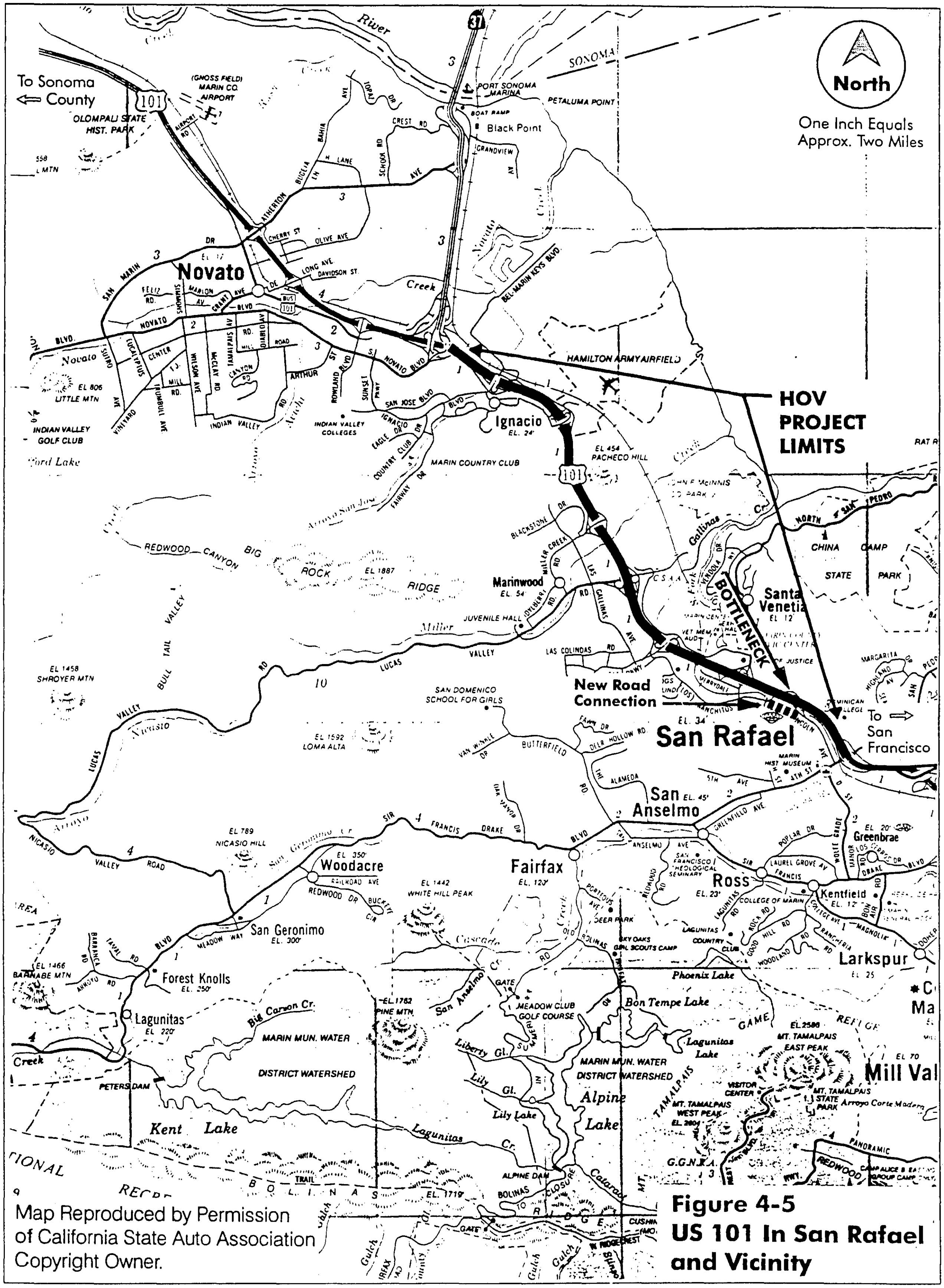

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Figure 4-5 US 101 In San Rafael and Vicinity

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downtown San Rafael has long been a bottleneck because there are no good surface street routes over this hill; traffic from both I-580 and US 101 funnels into this area, and there is a steep grade that reduces the capacity of the freeway at this location. US 101 is also a regional through route, and serves commuters travelling to jobs in Marin and San Francisco counties who live in Sonoma County to the north (population 420,000). US 101 also carries considerable recreational traffic to the north coast, and traffic congestion is typically worst on Friday afternoons between April and October.

This is considered one of the most congested freeways in the San Francisco Bay Area, according to annual monitoring reports prepared by Caltrans District 4. Traffic typically backs up for several miles each day in the southbound direction (travelling toward San Francisco) between 7AM and 9AM, and in the evening peak period in the northbound direction between 3:30 and 6:30 PM.

The capacity increase involved two components: first, HOV lanes (restricted to two or more persons per vehicle) were added to the freeway mainline in each direction. The project extends approximately six miles, from San Pedro Road north to SR 37 in Novato. The HOV restrictions are in effect from 6:30 - 8:30 AM in the southbound direction, and 4:30 to 7:00 PM in the northbound direction (Monday-Friday only). At other times, the lanes are open to all traffic. The northbound lane opened in August 1986, and the southbound lane opened in July 1987.

The second part of the project was the extension of a two-lane road, Lincoln Avenue, west of and parallel to 101, over the summit to connect with another existing road, Los Ranchitos Road. This provided a surface street route with one lane in each direction.

On the freeway itself, the southbound AM peak hour is currently 6:30 to 7:30 AM. During this period, 868 HOV's use the lane, carrying an estimated 3,760 persons, including bus passengers. The remaining three mixed flow lanes carry 6,380 persons in 5,550 vehicles. The HOV lane violation is generally seven to eight percent in both the AM and PM peaks. Caltrans estimates that over the 6.1 mile distance, AM peak HOV's (southbound) save six minutes, and PM peak HOV's save a negligible amount of time.

Before and After Capacity Expansion Traffic Volumes

Analysis was complicated by the fact that when Caltrans moved its District offices from San Francisco to Oakland in 1992, it disposed of all but the most recent hourly traffic counts.[10] Consequently, the only "before" traffic counts had to be taken from another report ("Marin 101 Contraflow Lane Evaluation,") which did not contain a full hourly set of counts. Attempts to locate other sources of before data were made, but did not yield any useful information.

Three hours of southbound and four hours of northbound traffic counts were available for comparison.[11] These are shown in Figure 4-6. The relevant comparison is with the "adjusted" line, because counts were not made at the exact same location. The counts indicate that during the six year period, hourly volumes grew by approximately 2,000-2,500 vehicles per hour (VPH) in the southbound direction AM peak, and 700-2,000 VPH in the northbound PM peak. The smaller growth in PM peak volumes is probably caused by the fact that at the bottleneck point (Puerto Suello Hill), the only freeway widening that took place was a new auxiliary lane in either direction, not "mainline" capacity for through vehicles. The bottleneck would have the impact of "metering" traffic heading into the count section, which was at North San Pedro Road. The theoretical maximum capacity in this area is about 8,000 VPH (4 lanes X 2,000 VPH per lane), which is nearly reached 4 and 6 PM.

Traffic volumes on the Lincoln-Los Ranchitos connector add an additional volume of 5,000 ADT, with 1,600 in the northbound direction, and 3,185 in the southbound direction. The connector is clearly being used as a congestion relieving route; the heavier southbound volumes are due to the fact that the connector is on the west side of the freeway, and it is much easier to use in the southbound direction to avoid congestion than in the northbound direction. Since no ADT's were available before-and-after for the freeway, it was difficult to relate this to new trips being made over Porto Suello hill.

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[10] Source: Telephone conversation with Bill Schott, Caltrans Highway Operations Branch.

[11] Because these counts were made at nearby but different locations, some adjustments had to be applied to account for intervening ramps.

Conclusions

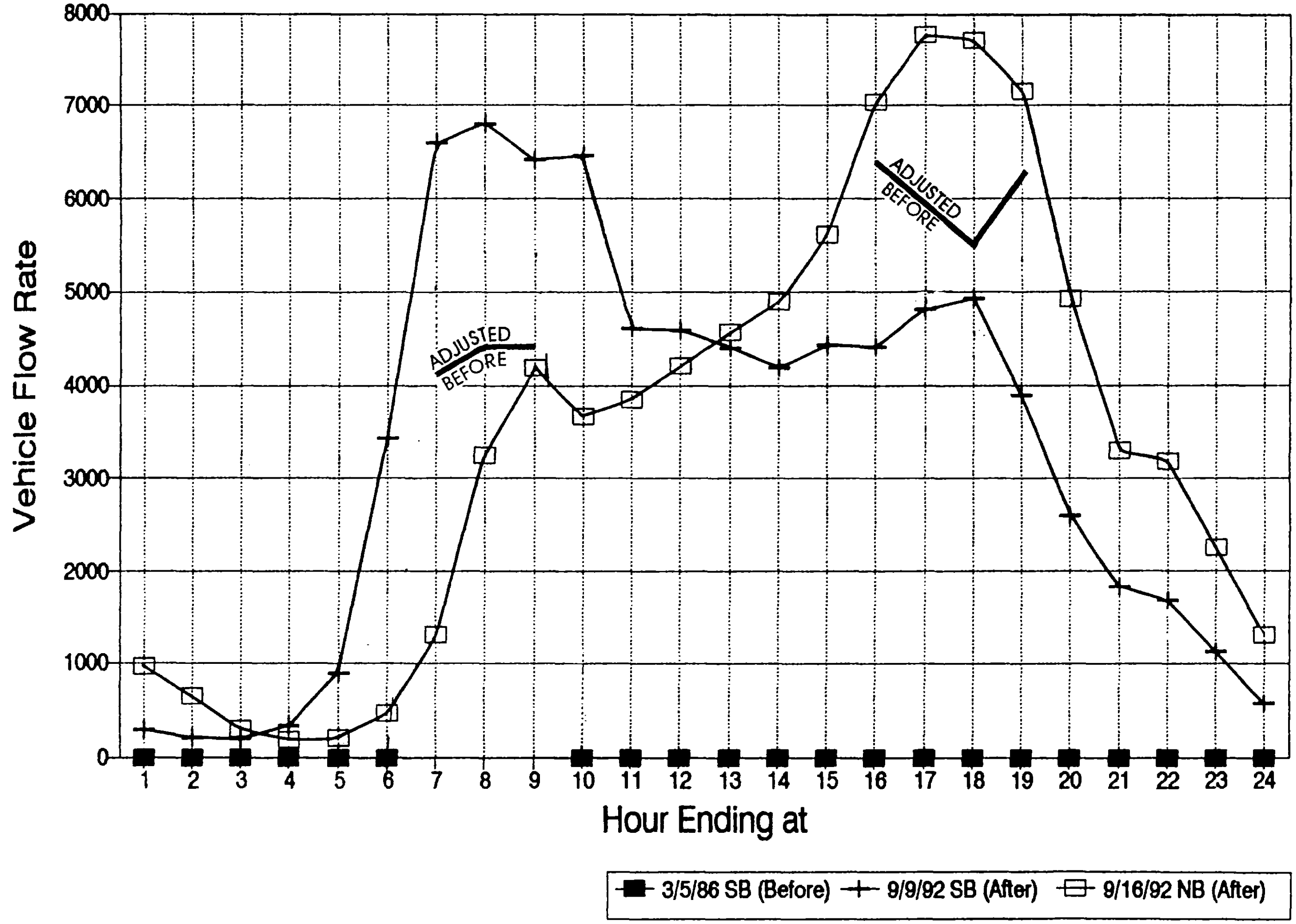
Traffic volumes in the peak period in the peak direction thus grew by roughly 50% in the AM, and 10-35% in the PM. However, employment growth was also occurring during this same time period. The closest comparison available is for 1985-1990 (five years), during which San Rafael's total jobs increased by 8%, and Marin County by 15%. Not all of the balance of the volumes can be attributed to induced travel, since it is not known to what extent traffic may have shifted from outside the peak to the peak period. Furthermore, it is likely that the "after" volumes may be higher due to seasonal effects; they were collected in early September '92 (vs. early March '86), and in this area weather is better and recreational traffic typically higher in September than in March.

4.2.4 Effect of 1989 Loma Prieta Earthquake on Capacity Reductions

One effect of the October 17, 1989 Loma Prieta earthquake was the loss of a significant amount of highway capacity in the Bay Area. Although the focus of the present study is of capacity *increases,* it is worthwhile to look at the effect of capacity reductions to see if the capacity effects are reversible, particularly because the capacity decrease took effect so rapidly.

The Bay Area facilities that were affected by the earthquake were **[16]** are shown on the map (Figure 4-7) and in Table 6 below:

Figure 4-6
US 101 Hourly Traffic Volumes at Freitas Parkway



Traffic Counts Taken at Milepost 13.7A

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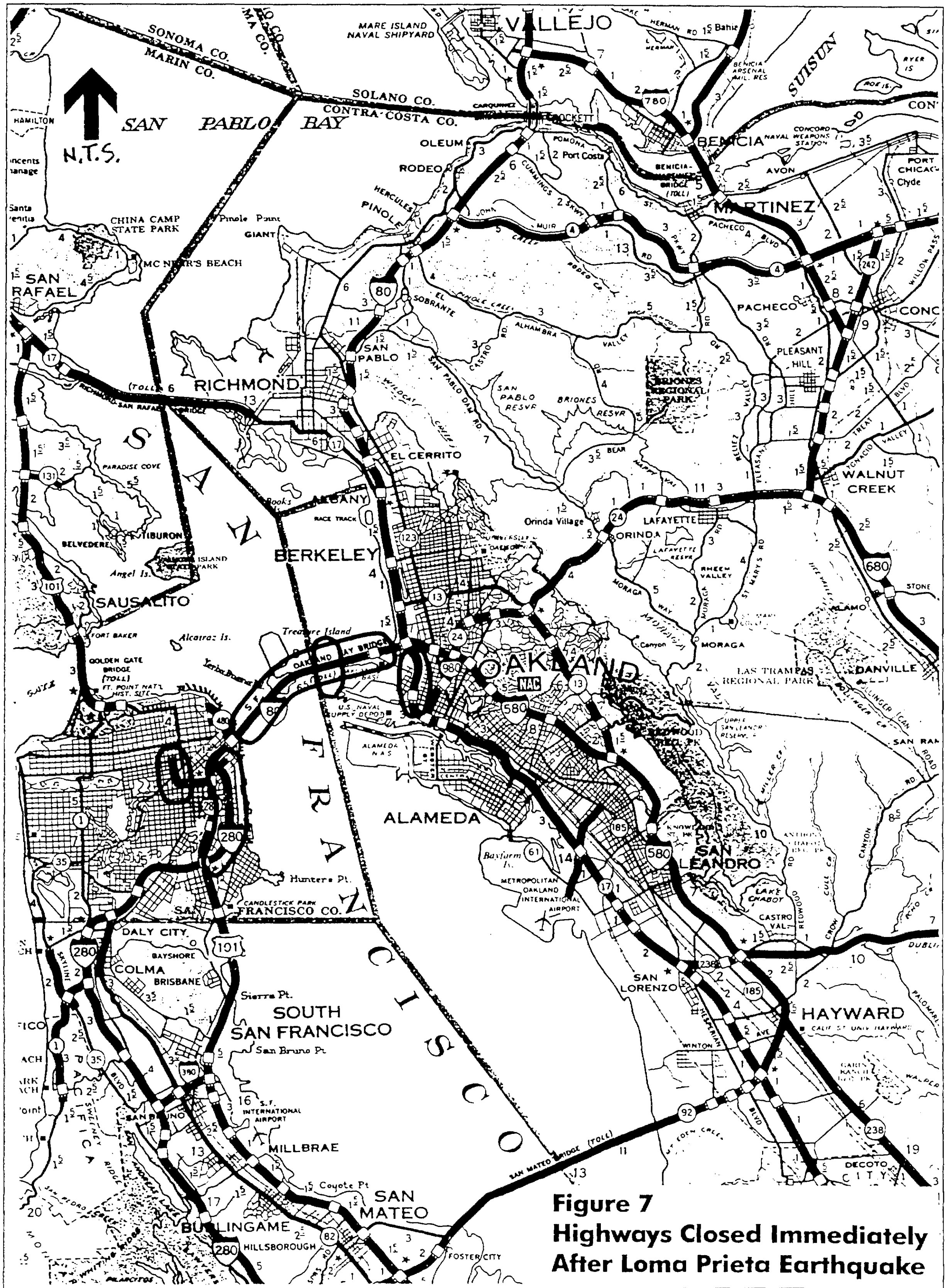

Figure 7
Highways Closed Immediately After Loma Prieta Earthquake

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Table 6
Bay Area Highway Facilities Affected by the October 1989 Loma Prieta Earthquake

Facility	Location	AADT*	Status
Bay Bridge	Transbay	242,000	Closed approximately 1 month
Cypress Structure	Oakland	150-190,000	Demolished
Embarcadero Freeway	San Francisco	115,000	Demolished
I-280	San Francisco	115,000	Part open 1993; completion 1994
Central Freeway	San Francisco	85,000	Portion demolished
Highway 17	Santa Cruz Mtns.	70,000	Closed approximately one month

* Annual average daily traffic; source: Caltrans, *Traffic Volumes,* 1989.

Other highway facilities were closed in Santa Cruz County, such as Highway 1 near Watsonville. Transportation agencies responded to this emergency in several ways that tended to enhance capacity: Caltrans restriped lanes and eliminated toll collections on transbay bridges at peak periods; BART began running more train service; ferries were added to provide transbay transport between the East Bay and San Francisco. Nevertheless, these improvements did not nearly make up for the capacity lost in the earthquake, and the results show how people will respond in the short term to major reductions in capacity and increases in travel time.
The primary impacts fell into three categories: *route diversions, modal diversions, and trip suppression.*

- Traffic at toll bridges nearest to the Bay Bridge, the San Mateo and Richmond bridges, increased by approximately 50 percent in the five hour peak period, which effectively represented the maximum traffic that these bridges could accommodate. Daily traffic volumes jumped 75 percent on the Richmond Bridge, and 65-70 percent on the San Mateo Bridge, indicating substantial shifts of traffic to the off-peak periods, when capacity was available.

- Within San Francisco, traffic spread over a wide area. According to the City's Department of Public Works, combined traffic volumes at eight key locations affected by the Central Freeway closure increased by 46,000 daily vehicles, an increase of 28% **[17]**.

- BART transbay ridership increased by more than 36,000 trips (115%) in the morning westbound peak, and by 127,000 (125%) trips during a 24-hour weekday in both directions **[12]**. About one third of new riders had never been on BART before. Newly organized ferry services carried about 10,500 transbay passengers at their peak, although ridership quickly declined after the Bay Bridge re-opened in mid-November 1989.

- Trip suppression took place as many travellers simply decided to forego trips. It appears that this effect in the transbay corridor was moderate, with about 10 to 15% of the total daily transbay person-trips foregone as a result of the bridge closure **[[18]**, based on a study by the Metropolitan Transportation Commission. Traffic volumes in certain other corridors actually decreased (e.g., at the Caldecott tunnels connecting the Bay plane and central Contra Costa County). Part of this may be attributed to temporary apprehension about using the remaining transportation facilities (such as BART's underwater tube) so soon after the earthquake. In Oakland, about half of all businesses reported losses in sales; San Francisco retailers also noted sales losses.

In the Peninsula corridor south of San Francisco, the closure of the double-deck section of I-280 increased congestion along the parallel US 101 freeway. This, combined with the increased downtown access time due to closure of the Embarcadero Freeway, substantially lengthened auto (and some bus users') travel time to and from San Francisco. BART trips in this corridor increased by about 2,600 per weekday. The Peninsula Commute Service (formerly Southern Pacific) rail line patronage increased by some 700-800 trips during the 6-9 AM commute period (an increase of 21%), and perhaps 2,000 daily trips. The long term effects are not known at this time. San Francisco has lost 10% of office jobs since 1990, mainly due to recession.

The conclusions from the study of Loma Prieta earthquake are:

- Impacts of highway capacity *reductions, at least in the short term,* appear to roughly correspond to the effects of new capacity. However, there is not enough data to make comparisons about the relative magnitudes. In particular, the affects varied widely for different travellers; even for transbay trips, some travellers experienced added travel times of only a few minutes, while others found their travel time increased by 30, 40, or even 60 minutes in each direction.

- A moderate number of discretionary trips can be suppressed, at least in the short term. These are typically non-work trips, such as shopping and social-recreational trips. Merchants were reported by the local press to have experienced significant drops in retail sales after the earthquake, persisting for some time afterward.

- Of trips that continue to be made, changes in timing/scheduling, and route choice, appeared to be the most prevalent impact. It should be noted that the number of suppressed trips seemed to diminish as time went on; suppression was greatest in the days immediately following the quake, and smallest immediately prior to the Bay Bridge's re-opening about a month later. This is an indication that certain trips could only be postponed so long, or that people were making accommodation to the additional travel time, and adjusting other activities to make room for the travel.

- Diversions to transit (BART) in the Bay Bridge corridor were significant, but represented only about a third of the total persons who had been making the trip prior to the Bridge's closure.

4.3 Canadian Experience

Canada provides an interesting contrast to the United States for the purposes of determining what effect highway capacity has had on travel behavior. The Canadian federal government never embarked upon a highway finance and construction program comparable to the interstate system in the U.S. Urban freeway construction largely had to be locally supported. This has resulted in either systems that were never completed (e.g., Montreal), or ones that were never begun (e.g., Vancouver).

In fact, in the late 1970's there were just over four times as many lane miles of urban freeway/expressway per capita for each metropolitan resident in the U.S. as there were in Canada (Goldberg and Mercer **[19]**, p.152).

Several factors make Canada a useful comparison to the U.S. experience:

- Canada, like the U.S., has generally experienced most of its development in the auto era, which began in the 1920's. Comparisons of U.S. and European cities are generally of limited value because most larger European cities had development patterns that were firmly set prior to the auto age. In many cases, development patterns of British/European cities were a result of the pre-mechanized "walking cities" than that of the railroad-dominated city of the 1860-1920 epoch.

- Both countries experience rapid population growth and economic development in the past 50 years. This is important because land use patterns and densities reflect he transportation technologies present when development occurred.

- Both countries have roughly comparable income levels. In 1989, the estimated GNP per capita was $19,020 in Canada and $20,910 in the U.S.[12] This is important, because income levels are known to have an important impact on automobile ownership, trip generation, and housing preferences.

- Both countries have high levels of home ownership: 63% in Canada versus 60% in the U.S. This contrasts sharply with European countries, where home ownership rates are usually much lower. However, there is more condominium and other multi-family owner-occupied housing in Canada than the U.S., which permits higher densities than the single family structure type so prevalent in the U.S.

There are also confounding factors that make the comparison between the two countries more complicated:

[12] Based on an exchange rates of C$1 = US$1.14. Changes in exchange rates since that time would have reduced the Canadian number somewhat, indicating a slightly wider discrepancy between the two countries. Source: *The World Almanac and Book of Facts 1992.* New York: Pharos Books.

- Gasoline taxes are higher in Canada than the U.S., though not as high as in European countries. In California, fuel taxes (excluding sales tax) have generally been in the 40 to 45% of *pre-tax* price of fuel; in Canada, they have generally been 55-60% of the pre-tax price. Also, in Canada motor fuel taxes are not all dedicated to road building or transportation projects as they are in California.

- U.S. tax policy has tended to be more favorable to decentralization of jobs and housing away from the central city than Canadian tax policy. For example, mortgage interest and property taxes are not tax deductible for Canadians, but substantial tax benefits accrue to Canadian investors in multi-family dwelling units, such as high-rise apartments.

- Land use policies of Canadian cities have been less lenient about the urbanization of areas near the edge of (or outlying) existing metropolitan areas.

- Lower urban crime rates in Canada have tended to make central cities, and especially their downtowns, more attractive places for living and working. There is less fear of travelling to downtowns at night, so many larger Canadian cities have retained their function as social and recreational areas where people will travel in the evening to eat, go to movies, and so on. Also, lower crime rates make living near the central business district a more acceptable alternative for middle income people, resulting in higher walk to work and transit usage rates.

- Canadian cities offer considerably higher quality transit services. Measured in revenue vehicle miles per capita, Canadian transit systems provide 2.4 times more service than their American counterparts do.

Despite these differences, a comparison between the two countries reveals some interesting insights:

- Work trip lengths (distances) are consistently shorter in Canada than in comparably sized American cities. Americans live nearly 25% farther from work than do Canadians. This appears to be a result of more compact urban form in Canadian cities.

- Despite this, *the amount of travel time spent in commuting to work is roughly the same in American in Canadian cities.* Put another way, the average Canadian commutes a much shorter distance but at a much lower speed than his American counterpart, resulting in little difference in journey-to-work travel time. This can be ascribed to slower highway speeds (due to congestion and/or a lack of freeways), and greater use of transit (discussed below), which is typically slower than driving. It also tends to support the hypothesis that people set up a relatively fixed budget of their time to allocate to travel, as discussed in Chapter 6.

- Canadian cities are considerably more transit oriented than U.S. cities. In fact, Vancouver has a modal mix not unlike Chicago, a metropolitan area nearly seven times its size. In the average American metro area in the mid-1970's, 13% of the commute trips were by public transit, but in Canada, 25% were. Transit ridership per capita is three times higher in Canadian cities than in the U.S.: 100 vs. 33 trips per capita in 1983.

  A pairwise comparison of the percentage of journey to work trips by various modes in Canada's three largest cities, and comparable American cities, is shown in the table below. A common characteristic is that both countries evidence increasing transit modal share with increasing metro area size.

- Carpool modal shares are nearly the same in the metro areas of both countries.

- Walking is considerably more prevalent for the journey to work in Canada (eight percent of commuters) than it is in the U.S. (five percent of the population). In neither country, however, is walking as significant as a motorized mode of travel.

- Personal automobile ownership rates are roughly 25% lower in Canada than they are in the U.S. In 1987 there were .42 personal autos for every Canadian, while in the U.S., there were nearly .57.

Conclusions from Canadian Comparisons

The Canadian/U.S. comparison reinforces those tendencies noted in the three California case studies examined earlier in this chapter. Namely, they highlight the intimate relationship of supply, demand, and public policy effects-- and the difficulty of untangling those effects. It is likely that partly *because* of Canada's decision not to pay for freeways, far fewer were built in Canada than the U.S. With fewer freeways and less pressure to decentralize, Canadian cities could afford to provide higher quality transit services.[13] The higher quality transit services was supportive of the central city's capturing a large share of the new development occurring in the metropolitan area, which in turn made the central city a more attractive place to live and work.

The lack of urban freeways in Canada has unquestionably led to lower travel speeds and presumably more intense congestion (partly because more traffic converges upon the central business district than in U.S. metro areas). However, the reduced traffic speed has been offset by shorter commute distances, leaving the average travel time to work roughly equal. In order to do this, more Canadians must live in higher density surroundings, and are more often found in multi-family dwelling units than in U.S. metro areas.

[13] Toronto opened its first subway in the 1950's, Montreal in the 1960's, and Vancouver in the mid-1980's. Few U.S. metro areas in their size class had rail systems until the 1980's.

Table 7
Comparison of Journey-to-Work Transit Modal Share in Canadian and U.S. Metropolitan Areas
(latest census population in parentheses, in 000)

Montreal (pop. 3,127) compared to:	*34%*	
Atlanta (2,834)		5
Baltimore (2,382)		6
Miami-Fort Lauderdale (3,193)		4
Minneapolis-St. Paul (2,464)		5
Toronto (pop. 3,893) compared to:	*27*	
Boston-Lawrence-Salem (4,172)		10
Detroit-Ann Arbor (4,665)		2
Houston-Galveston (3,711)		4
San Francisco-Oakland (3,687)		18
Washington, DC (3,924)		13
Vancouver (pop. 1,603) compared to:	*15*	
Denver (1,848)		4
Seattle (2,559)		6
Portland (1,478)		5
San Diego (2,498)		3
Sacramento (1,481)		2

Source: For US metro areas, from *Journey-to-Work Trends in the United States and its Major Metropolitan Areas, 1960-1990,* US DOT/Federal Highway Administration (based on 1990 data). For Canadian metro areas, from "Public Transportation Developments: Canada vs. The United States," in *Transportation Quarterly* (vol. 48 no. 1), Winter 1994. All figures are for entire metropolitan area. Population is in thousands, and figure is for 1991 for Canadian metro areas, 1990 for U.S. San Francisco-Oakland includes five-county central Bay Area only.

Although the comparisons noted above are interesting, the policy implications may not be easily transferred to the U.S. U.S. metro areas already have an extensive system of urban freeways; the Canadian experience suggests 'what might have been' had American metro areas not embarked upon a major freeway building program in the 1950's and 1960's. The reversibility of the effect is not as clear, i.e., it is not clear that as American urban areas reach Canadian levels of urban congestion that they will experience Canadian-type land use forms and commuting patterns. Arguing that the development trends of the last half century can be reversed by applying Canadian land use policies now may be somewhat akin to trying to unscramble an omelette.

As noted, public policy and other exogenous factors are dramatically different in Canada, and were more strongly supportive of central cities during their formative development. Perhaps most clearly, the Canadian experience supports the contention that people do have travel time budgets, and point to a strong resistance to spending more than 60 minutes a day for commuting.

4.4 Problems With Case Study Approach

One of the major conclusions of this section is that it emphasizes the shortcomings of the case study approach. Briefly, those shortcomings fall into the following categories:

- Control of exogenous variables (e.g., economic conditions)
- Completeness of data sets
- Differences/comparability of forecast years
- Institutional bias
- Differences in forecasting techniques and sophistication

First, transportation changes take place in a highly dynamic environment: variables such as household income, population, employment, fuel and parking prices, and other variables cannot be directly controlled for. In laboratory conditions, scientists can control for all other factors except those being varied, but transportation planners cannot. It is difficult using a time series (before/after) approach to control for the distributional shifts in land use activities that transportation investments may generate if the area of analysis is limited. This creates a considerable problem in distinguishing between a shift *along* the demand curve (due to the reduced price of travel caused by added capacity), and a shift in *the demand curve itself* (see Figure 4-8). Demand curves may shift due to changes in income, tastes, demographic factors, and so forth. Point number 1 represents the initial conditions; point 2 is the result of a capacity increase (travel time reduction); point 3 is the result of demand curve shift; and point 4 is the combined result of capacity and demand increase.

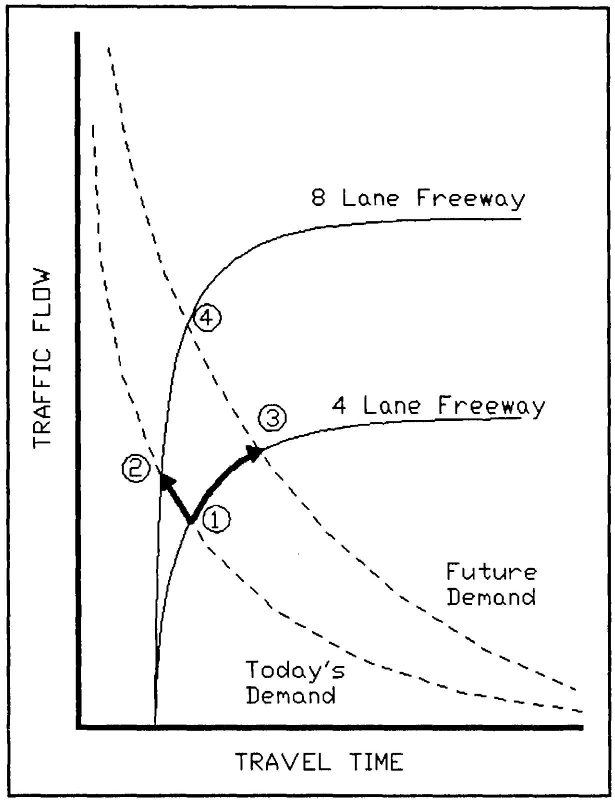
Second, the data requirements of a case study approach require that there be (as a minimum) traffic counts on the new facility and parallel routes on an annual basis, along with good records of land use changes in the corridor. Caltrans' *Traffic Volumes* (published annually) contains only data on State highways (not parallel city or county streets), and uses a set of "control stations" to factor up route segments. In many cases, these control stations can be many miles apart, and may not be reflective of actual conditions "on the ground." Because of budget limitations, the counting program may have been better in some years than others, leading to biased results. In some cases, historical data have been lost.

Local agencies often lack consistent annual count programs with counters placed at the correct locations to assess changes in corridor demand due to capacity changes. Even if all of the count data were perfectly available, it may not have the appropriate temporal resolution needed to assess the impacts of new capacity. Ideally, counts would need to be available at fifteen minute intervals, to assess the impacts of temporal shifting in travel.

Third, income and other demographic changes should ideally be addressed. Changes in real incomes and family size (life cycle issues) typically induce higher levels of auto ownership and a desire for more residential space. Detailed geographic information at the corridor level is usually available only from the US Census, which is conducted too infrequently (every ten years) to be useful.
Fourth, information would need to be available on paralleling transit services; even then, one would not know what the changes in destination choices were (were people driving further because of the new capacity in order to reach a "better" destination; or the shifts in land uses that took place over time.

Fifth, because forecasting for different projects is done using varying forecast years, and since the forecasting models may have been defective in the first place; or done using different assumptions that represent philosophical artifacts from the era in which they were produced.it is not possible to attribute differences between forecasted and actual travel volumes to induced travel. The forecasts may contain an institutional bias, perhaps unconscious, that tends to support the construction of a facility. An agency may make reasonable assumptions within a "gray area" of discretion that favors the action that the constructing agency wishes to take. This bias can vary with time, place, and the individuals involved, but can all lead to forecasting errors.

Figure 4-8 Demand vs. Capacity Changes



In the late 1970's, a committee of the Institute of Transportation Engineers (ITE, 1980) tried to use this approach for other purposes, but concluded:

Originally, it was intended to examine the accuracy of forecast travel demand on major transportation facilities that had been subsequently constructed. Forecast traffic volumes on freeways and expressways... were to be compared to actual use patterns. However, as the committee pursued its analysis, there was an admonition that kept recurring regarding that kind of analysis. The travel demand forecasts made for facilities that had been constructed since the initial forecast had been made in the context of larger transportation systems. Many elements of these systems had either not been constructed or not constructed as assumed when making the original forecasts. Thus, the comparison of observed travel demands on the operational portions of the system with the original forecast would be specious. Consequently, it was decided not to pursue this type of comparison.

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