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A Study Of Freeway Capacity Increases In The San Francisco Bay Area And Greater Sacramento

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Abstract

This study evaluates the adequacy of freeway capacity increases' air quality analyses and the accuracy of their predictions of future traffic volumes. New-alignment freeways, freeway lane additions, and freeway interchange additions or expansions in the greater Sacramento and greater San Francisco Bay Areas, planned in the last 10 years, were all included in the study. The CEQA and/or NEPA documents for these projects gave the needed air quality analyses and traffic predictions.

The study revealed simplistic air quality analyses. Only 22% of the projects analyzed mesoscale emissions of CO, NO_x, and hydrocarbons; the rest of the projects had only microscale analysis of CO emissions or no quantitative emissions analysis whatsoever. Despite a shortage of detailed traffic count data in the Bay Area, the study showed a pattern of traffic projections that significantly underpredicted the observed actual volumes. Thus, these freeway capacity increases appear not to have had the predicted regional air quality benefits, but instead have likely worsened air quality.

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-Caltrans Headquarters, Sacramento. Offices of Environmental Analysis and Traffic.
-Federal Highway Administration, Region IX, San Francisco.

Despite the assistance provided by the above individuals as well as dozens elsewhere, any errors in this study are solely attributable to the author. Furthermore, the views and opinions expressed herein are not those of the U.S. EPA, but are rather those of the author alone.

EXECUTIVE SUMMARY

The purpose of this research is to evaluate, for projects that increase freeway capacity, the adequacy of their air quality analyses and the accuracy of their traffic predictions. The study examines three types of capacity-increasing measures on limited-access, divided highways ("freeways") in the greater San Francisco Bay Area and greater Sacramento regions: 1) new-alignment freeways, 2) expansion of existing freeways by adding "mixed-flow" and/or high-occupancy vehicle (HOV, or diamond) lanes, and 3) adding or expanding interchanges on existing freeways. Such projects are required under the California Environmental Quality Act (CEQA) and/or the National Environmental Policy Act (NEPA) to undergo environmental review prior to their construction.

By limiting the study to all such projects for which the final environmental document is less than 10 years old (and adding a few additional projects that were one or two years older), there exist 27 such freeway projects. I looked at the level of detail of the air quality analysis for all these in Part I of the study. In Part II I compared, for those projects on which construction had been completed, the projected future traffic volumes with actual volumes as determined by traffic counts.

The large majority (63%) of the 27 capacity-increasing

projects analyzed only carbon monoxide (CO) air quality in the immediate freeway vicinity. 22% of the projects had more detailed air quality analysis, which typically also involved mesoscale analysis of outputs of CO, hydrocarbons (HC), and oxides of nitrogen (NO_x). 15% of the projects had no quantitative studies of air quality effects.

The second half of the study, comparing traffic projections to observed volumes, revealed serious shortages of traffic count information, as well as extremely simplistic projections in the original environmental documentation. Because of these and other problems with the data, a precise quantitative assessment of the accuracy of traffic volume forecasting was not possible. However, in 5 of the 6 cases in this portion of the study, traffic projections underpredicted the later observed volumes.

This study does not determine the reason for the underprediction. Induced trips or latent demand, unexpected growth, and other factors are all probable partial causes. Whatever the reasons for repeated underprediction, the predicted air quality benefits that were used to justify the projects' construction may never have materialized. In fact, these projects likely had overall negative impacts on air quality in the short run. Their long run effect on air quality, while still undocumented, may be even more negative, since travel and population growth are likely to continue to exceed the forecasts made in these projects' environmental documents.

Given the past underprediction of traffic volumes, future

freeway projects analyzed using standard traffic forecasting techniques that advertise regional air quality benefits should be viewed cautiously by air pollution officials. The environmental planning process would benefit greatly from improved traffic forecasting. Improving traffic count data is a critical step toward achieving this goal. Additionally, the air quality analyses of all these projects should model the consequences of the freeway expansion not only on the emissions of CO, but on the emissions of HC, NO_x, and PM-10 (small particulates) as well.

PURPOSE

Despite the toughest air pollution regulations in the U.S., most Californians are still forced to breathe unhealthy air. The total annual costs of this pollution have been estimated by many economists to be in the billions of dollars. Countless studies have documented that this sorry state of affairs is largely a result of motor vehicle use.

Increases to freeway capacity have the potential to significantly affect air quality. The environmental planning process under the National Environmental Policy Act (NEPA) and/or the California Environmental Quality Act (CEQA) is the only point at which the air quality effects of capacity increases are examined on an individual project, as opposed to a regional, basis. Thus, it is imperative that the air quality analyses in this planning process be accurate, as well as adequate.

I undertook a two-part evaluation of the adequacy of the environmental planning process for projects that increase freeway capacity. First, I evaluated the project's air quality analysis, and then compared the traffic volumes projected for the improved freeway to the actual traffic volumes observed after it was completed. I present the background information, the findings, and a discussion of the findings for each of these two halves of the study in Parts I and II below.

PART I.

A. Background and Methodology

The analysis included the following three types of projects in the greater San Francisco Bay Area and the greater Sacramento regions: 1) new freeways; 2) expansions of existing freeways by adding mixed flow (i.e., no restrictions on use) and/or HOV (use limited to vehicles with a minimum number of passengers) lanes; and 3) projects that added new freeway interchanges or expanded existing interchanges. I included only projects for which the final environmental document had been completed in the last 10 to 12 years. Today these projects are in various stages of development. Some projects are completed, some are under construction, and some are still in the planning stage.

The National Environmental Policy Act (NEPA), and the California Environmental Quality Act (CEQA), NEPA's state corollary, require that the environmental consequences of freeway expansion projects be evaluated prior to the project's initiation. Both laws require similar environmental documents for these projects. First, a federal Environmental Assessment (EA) or a state Initial Study (IS) must be prepared. If the environmental consequences of the planned work are deemed relatively insignificant, the final federal document is a Finding of No Significant Impact (FONSI) while the final state document is a Negative Declaration (ND). If the consequences are deemed to be more major, then the federal and state documents prepared are an Environmental Impact Statement (EIS) or Report (EIR),

respectively.

Some of the roadwork I looked at was subject to both laws, whereas other projects were only covered by one. In the 1950's and 1960's when the U.S. interstate program was under full construction, the bulk of the funding for such projects was federal. Under the Reagan-era "new Federalism" of the 1980's, the federal money was very limited.

For projects that are built without any federal funds, and that are not connected to federal or federal aid highways, only CEQA applies. In the Bay Area, the number of projects subject only to CEQA is rising dramatically. The majority of planned capacity increases are being financed by local or countywide initiatives that raise sales taxes for highway dollars. This shift in freeway funding is of significance to the EPA, for virtually all projects subject only to CEQA regulation are not routinely reviewed by Region IX. Also, the EIR's prepared directly by or for county or local governments are increasing. With Caltrans no longer being the sole preparer, there will likely be an increasing range in the quality of the EIR's.

There were 21 projects in the Bay Area and 6 projects in the greater Sacramento region that met the previously stated criteria. These are listed in Table 1.

In reviewing the environmental documents for each of these 27 projects, the first part of this study looked at the level of detail of the air quality analysis of each project. In addition

TABLE 1: The Title, Type, and Date of the Projects' Environmental Documents

Abbreviations: I/C = interchange EA = Environmental Assessment IS = Initial Study ND = Negative Declaration FONSI = Findings of No Significant Impact DEIS/FEIS = Draft/Final environmental impact statement FEIR = Final Environmental Impact Report

Greater Bay Area projects:

1. *EA and IS for two new I/C's at Stoneridge Drive on I-680 and Hacienda Drive on I-580 in Pleasanton, modify existing I/C on 580, and build auxiliary lanes on 580 and 680,* 12/87.

2. *EA/IS for Widening from 4 to 6 Lanes and Construction of 2 Sound Barrier Walls on I-880 in Alameda and Santa Clara Counties,* 6/88.

3. *DEIS: I-80 and I-180. Operational Improvements in Alameda and Contra Costa Counties,* 1/83.

4. *FEIS and 4(f) Statement. Route 101 in Santa Clara County, 0.6 miles south of Cochrane Road in Morgan Hill to 0.7 miles North of Route 82 in San Jose,* 7/78.

5. *ND/FONSI. Widening Route 101 from 6 to 8 Lanes in Santa Clara County from the Lawrence Expressway to the San Mateo County Line,* 10/86.

6. *IS/EA. Widening Route 101 from 4 Lanes to 6 Lanes in San Jose, from San Antonio St. to the McKee Rd. I/C. Santa Clara County,* 7/87.

7. *ND. Widening 101 from the 280/680/101 I/C North to the De La Cruz/Trimble Rd. I/C,* 4/89.

8. *ND. 101 Widening from Bernal Rd. to the 280/680 I/C,* 5/88.

9. *FEIS. Reconstruction of the 680/24 I/C and Freeway Improvements,* 7/87.

10. *FONSI/ND. Proposed new I/C at Bollinger Canyon Rd., Widening of Overcrossing, and Modification of Crow Canyon Rd. and Sycamore Valley I/C's on I-680,* 9/83.

11. *ND/FONSI. Proposed Widening and Auxiliary Lanes on I-280 in Santa Clara County,* 1/87.

12. *ND/FONSI. Freeway Widening in the Median of I-680 from Willow Pass Rd. to Marina Vista Boulevard,* 10/88.

14. *EA/IS for Concord Avenue/Market St./Route 242 Ramps Project,* 6/86.

15. *FEIS. I-180 [the Hoffman Freeway],* 6/81.

16. *DEIS. Route 92 Gap Closure and 92/101 I/C Completion,* 2/79.

17. *EA. Construct 4-lane Freeway from Mini Dr. to Sage St. Overcrossing with Diamond I/C at Fairgrounds Dr., Vallejo, Solano County,* 11/85.

18. *EA/IS. Reconstruction of I-80/Alamo Dr. I/C in Vacaville, Solano County,* 10/86.

TABLE 1 (continued)

19. *ND/FONSI. Proposed Widening of Route 152 in Santa Clara County,* 4/87.

20. *EA. Proposed Ramp Connection for Route 238 West to Route 17/I-880 South, in and near San Leandro, Alameda County,* 3/85.

21. *ND/FONSI. Ramp, Road, Overcrossing and Signals Construction, Modification, Widening, and Installation on Route 237 in Santa Clara County at Fair Oaks Avenue,* 2/83.

Greater Sacramento region projects:

22. *Environmental Reevaluation. Route 99 [rural highway converted to 4-lane freeway],* 12/83. [FEIS, 8/75].

23. *FEIS. Roseville Bypass [Route 65],* 9/84.

24. *ND/FONSI. Route 99. Build 2 lanes in the median in Sacramento County between Mack Road overcrossing and Sacramento Blvd. overcrossing,* 10/87.

25. *FEIR. Silva Valley Parkway I/C with I-50,* 2/90.

26. *IS. Laguna Blvd./Route 99 I/C Reconstruction,* 2/88.

27. *FONSI. North Natomas Freeway Improvements,* 1/90.

to a final EIS/R or FONSI/ND, most of the projects had at least one supplementary technical report. These reports present the results of the air quality models used to predict the effect of the increased freeway capacity on the emission of pollutants. Additionally, these reports often contained the traffic forecasts used in Part II of this study.

B. Findings and Discussion

All of the 27 air quality analyses in this report concluded that the project would improve air quality (although not necessarily by a significant margin), or would result in no

significant change in air quality. For 17 of the 27 projects (63%), the air quality analysis consisted of a microscale study of only CO (carbon monoxide) emissions. Analyzing the effects of only one pollutant often was justified by the inaccurate conclusion that CO serves as an "indication of the full range of pollutants"[1]. The effects of a project on the full range of air pollutants, however, can not be estimated by CO emissions. In general, increasing the average travel speed on a freeway from a congested, stop-and-go condition to a steady flow decreases the emissions of both CO and total HC (hydrocarbons), but increases the emissions of NO_x (oxides of nitrogen). Furthermore, the impacts of CO are localized, but the formation of ozone from HC and NO_x affects the larger air basin.

Only 6 of the 27 projects (22%) had both a microscale analysis of CO emissions and a mesoscale analysis of emissions of CO, HC, and NO_x. Five of these 6 projects were of enough significance to require an EIS. Two projects requiring an EIS did only a microscale CO analysis. One of the 6 mesoscale analyses projected emissions of SO_x and particulate matter, and divided HC predictions into total and nonmethylated hydrocarbons. Another included a prediction of project-caused lead emissions.

Four of the 27 projects (15%) had <u>no</u> quantitative analysis of air quality. One such project justified this minimalist approach as follows: "Based on previous analysis [of different

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[1] (EA, <u>Construct 4-Lane Freeway from Mini Dr. to Sage St. Overcrossing... in Vallejo, Solano County</u>, 11/85).

projects]... no significant impact... is anticipated"[2]. Another justification was that because the project was predicted to decrease total vehicles miles traveled (VMT) as well as congestion, the project will benefit air quality, and thus quantitative analysis is not required[3]. Of these 4 projects with no quantitative analysis, 3 were interchange projects, while the fourth was a freeway-to-freeway ramp project. Given that both the Bay Area and Sacramento are violating federal and state standards for ozone and CO, adequate air quality analyses for all these projects would have predicted the effect on emissions of CO, and the ozone building blocks HC and NO_x. Additionally, Sacramento is violating the federal standard for small particulate matter (PM-10)[4]. Only one of the 27 projects modeled what its consequences would be for either PM-10 or TSP.

A shortcoming of these models is that, for interchange additions or expansions, they tend not to model the consequences of additional traffic on the mainline, but simply look at the emissions of the cars on the ramp. This is a significant oversight. If the mainline is congested or nearly so, these entering vehicles can bog down the mainline enough so that total emissions of CO and HC may increase dramatically. Thus the

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[2] (EA/IS, Reconstruction of the 80/Alamo Drive Interchange (I/C) in Vacaville, Solano County, 10/86).

[3] (EA/IS, Two new I/C's at Stoneridge Dr. on 680 and Hacienda Dr. on 580 in Pleasonton, modify existing I/C, and build auxiliary lanes..., 12/87).

[4] PM-10 replaced total suspended particulates (TSP) as a criteria pollutant in 1987.

addition of extra vehicles to a freeway near saturation not only negatively affects air quality through the emissions from the new traffic, but also by increasing emissions from all the vehicles on the freeway. Although ramp metering might mitigate this problem, many interchanges and ramps are still being built without ramp metering, and the air quality analyses are typically done for a scenario without metering.

None of the projects gave a qualitative, let alone quantitative, analysis of the effects of the increased capacity on carbon dioxide emissions. This is a serious shortcoming, for CO_2 is the primary "greenhouse gas," which when emitted contributes to the problem of global warming. Carbon dioxide is not directly harmful to individuals, but rather in sufficient quantities damages our planet's atmosphere.

While both the Reagan and Bush administrations have shown great reluctance to limit CO_2 emissions, these emissions will have to be reduced. In California, over half the carbon emissions are from our transportation network.[5] CO_2 emissions are tied directly to fuel consumption. Thus, a vehicle idling in stop-and-go, congested traffic is maximizing CO_2 output.

Another shortcoming concerned mitigation of project-caused air quality declines. One air quality analysis stated that "air quality will be monitored to determine the need for ramp metering

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[5] The Impacts of Global Warming on California, California Energy Commission, p. c-1. August, 1989.

to avoid significant air quality impacts."[6] No timetable of when or where such monitoring would be done was provided, however. Nor were critical pollutant levels specified which would trigger the installation of ramp metering. Without a specified implementation plan, it is unclear whether mitigation measures will be actually carried out. Therefore, it is questionable whether the measures should be given much weight when evaluating the project impacts. A recent CEQA amendment now requires monitoring plans for mitigation measures in final CEQA documents, which may improve the situation.

PART II.

A. Background

A wide number of varying factors, such as average fuel economy, percentage trucks, and pollution control standards, are used in the air quality analysis for a capacity-increasing highway project. The most critical component of these models are traffic volumes for both the build and no build scenarios. Thus a critical first step to check the accuracy of the air quality impact analysis for a project is to compare actual traffic to the predicted traffic used in the emissions model. The second major part of the study did just that and compared the projected

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[6] (ND, Widening 101... in Santa Clara County from the Lawrence Expressway to the San Mateo County Line, 10/86).

traffic volumes to the actual volumes as measured by counts on completed projects.

Before presenting the results of these comparisons, I first discuss problems in the modeling process as well as limitations to the data used in this part of the study.

Traffic modeling is a complex process, but its essence is that land use, growth forecasts, and socioeconomic data are used to predict numbers, origins, and destinations of future trips. Various models then assign these trips to modes (transit, private vehicles, carpools, etc.), times, and roadways, using travel time, expenses, and other factors. Certainly any attempt to predict the future is an inexact art, and predicting traffic volumes is especially tricky, given the enormous range of variables that potentially affect travel. These factors include gas, transit, parking, and toll prices, changes in regional growth patterns, new travel options, earthquakes, etc.

Although these models are highly sophisticated, they contain two serious flaws. First, they treat land use strictly as an explanatory variable for highway use. Although land use certainly helps explain observed highway use, it is also true that freeway location and congestion levels influence the land use decisions.

Historically, land use decisions in this country have been made at the local level. Regional or state planning attempts at more centralized land use planning are typically controversial and are often challenged successfully in the courts or through

voter initiatives. Caltrans and FHWA are thus extremely reluctant to appear to be making land use decisions. Officials at these agencies maintain that roads are expanded to meet the demand provided by present and future land uses, as decided by local governments. Their position is that these projects are often undertaken to fulfill existing needs for greater freeway capacity, so any influence on land use is minimal.

While it may be acknowledged that highways influence land use through market forces, highway agencies maintain that the responsibility for changes in land use that arise lie with the local governments who set policy through zoning and other mechanisms. An apolitical examination reveals that where and when roads are expanded or built has the potential for tremendous impacts on regional growth and development. Several senior Caltrans officials agreed off-the-record that this is the case, but agency policy refuses to acknowledge this.

This debate, over whether growth causes the highways or highways cause the growth, is often polarizing and acrimonious, with Caltrans and environmental groups exchanging heated rhetoric both in the press and in the courts. Rarely does either side cite controlled or quantitative studies to reinforce their position, although there is a body of literature on this subject. (See Appendix A). Certainly the issue does not lend itself readily to quantitative study. Difficulties include the abundance of confounding variables, and the need for controls combined with the problem of finding areas similar in all aspects

but for freeway improvements. After reviewing the literature, it appears that the effects of roadwork on growth are variable and site specific. While growth is limited without an adequate transportation network, such a network is not of itself sufficient to ensure that growth will follow. Other factors, such as sewage lines and nonrestrictive zoning, are also required.

The second theoretical flaw in traffic models is that the models do not include feedback loops to record the effect of increased capacity on the public's demand for or use of the facility. Demand, and thus the trips generated, are assumed to be the same both before and after the capacity increases are completed. Most models in use today do allow and account for diversion of trips to other routes or modes, but not for new trips. Thus, the models show that increased freeway capacity may increase traffic volumes, but only by diverting (capturing) vehicles from, e.g., local arterials, or capturing trips from existing transit riders.

In highly congested areas such as the urban regions of California, many individuals are either foregoing automobile trips altogether or have altered their destinations and/or travel times to avoid peak hour congestion. Called "discouraged drivers," they create a "latent demand" for improved road conditions. These phenomena are not addressed by traffic projection models currently in use. When the capacity on a freeway is increased, very likely some of these discouraged

drivers will return to their vehicles on the expanded roadway, leading to new "induced trips."

Even if transportation agencies were to acknowledge the existence of pre-construction latent demand and post-construction induced trips, the new trips would be difficult to quantify. One hypothetical way to measure induced trips would be to observe traffic volumes on the freeway or ramp immediately prior to construction commencing, and then to record the volumes after construction. Any increase in traffic could be attributed directly to induced trips. This information could then be used to develop models to predict induced trips.

The problem with this approach is that other variables besides induced trips could explain the difference between these two volumes. For example, unexpected regional growth including increased housing and commercial, industrial, or retail development would increase traffic, while improved transit or traffic signal coordination on parallel arterials would decrease traffic.

This problem would be minimal if the planning and construction periods were very short, and the traffic was counted immediately before and shortly after construction. Most of the freeway capacity increases studied, however, took a year or often much longer to complete, allowing greater amplitude in the confounding variables. Also, as will be discussed in detail later, traffic counts are done very infrequently in the Bay Area.

Another problem in quantifying induced trips is in

accurately measuring the types of responses to road expansions: shifts in mode, travel time, route, and destination. Route shifts, for example from arterials to the improved freeway, prove difficult to assess since few arterials are regularly counted. In the Bay Area, few towns other than Berkeley and San Jose have regular counts of their arterials, although this non-freeway network is included in the traffic models. Mode shifts, e.g., from vanpools to single occupant vehicles, would also confuse the issue, in this example by having some of the traffic increases due not to induced trips.

One theoretically valid way to quantify induced trips is to conduct interviews with drivers. Interviews could take place on the completed roads that have a tollbridge or plaza; realistically, this seems unlikely because of the time required. A large cohort study might also yield useful data. Regional travelers could be questioned on their behaviors before and after the roadwork. Problems with this approach include the high time costs of gathering the data and the possibility of unreliable data, due to respondents' untruthfulness or forgetfulness.

The primary rationale for the construction of the vast majority of the 27 freeway projects examined was decreased congestion. The benefits attributed to reduced congestion are better service to the drivers and improved air quality. Two problems underlie this reasoning. First the assumption that lessened congestion equals improved air quality is problematic. Although CO and hydrocarbon emissions are reduced as congestion

decreases, NO_x emissions are increased. Ozone, the major smog ingredient, is produced by the sunlight-aided reaction of reactive organic gases (from hydrocarbons) with oxides of nitrogen. While both smog ingredients have a number of sources other than vehicles, and high levels of NO_x may curb ozone levels, it is simplistic to say that decreasing one ingredient at the expense of the other improves air quality.

Secondly, as mentioned previously, capacity increases do not always result in decreased congestion, especially in the long run. Reiterating, roadway improvements have the ability to spur regional growth and thus attract more trips, and the latent demand for better roads creates post-completion induced trips. In the short run, before development can occur and before people change their driving habits to take advantage of the uncongested road, emissions of CO and hydrocarbons may very well decrease. However, in the long run, as induced trips and/or regional growth occur, these emissions may go up. The roadway may end up congested, but now with more vehicles and thus more emissions than it had previously.

Despite the problems mentioned previously with quantifying induced trips, it is still valuable to compare traffic projections to actual counts. I could only find two instances where this has ever been done in the U.S., and both are small, limited studies. The Transportation Studies Center, a research branch of the Department of Transportation, has agreed to provide FHWA's Office of Planning with such a study. The research will

tentatively look at 7 or 8 major highway projects from around the country, and will compare actual costs to predicted costs in addition to traffic volumes. The results from this modestly-sized study (FHWA HPN-23) will not be available for perhaps a year, however.

B. Limitations of Data

Comparing traffic projections to volumes was difficult. Due to lengthy construction time, unresolved environmental problems, or shortage of funds, 21 of the 27 projects I examined were not yet completed. One of the projects actually made no prediction of future traffic volumes[7].

Often the traffic projections in the EA/IS or EIS/R were not predictions of volumes (numbers of cars on the road), but rather of minutes of delay. Underlying this delay data were the volume predictions, but locating the volume numbers was not straightforward. Sometimes they could be found in one or more of the technical appendices, such as the Noise/Air/Energy reports. For other projects, I obtained the needed data from the original computer model printouts.

To accurately model vehicle emissions at any point, at the barest minimum, projections of the following are required for each of the freeway's directions of travel: the average annual daily traffic (AADT; given in total vehicles per day), and the

[7] (Environmental Document, Ramp... on 237 in Santa Clara County at Fair Oaks Avenue, 2/83).

a.m. and p.m. peak hour volumes. This latter figure is usually defined for urban areas as the number of vehicles passing the point in the tenth busiest hour of the year[8].

Sometimes the traffic predictions were extremely crude. For example, some projects did not make predictions for each travel direction on the freeway, but rather lumped both directions into ADT (average daily traffic) and peak hour projections[9]. Sometimes the ADT figure was stated to be the AADT; other times it was unclear if the ADT was the AADT or the ADT for the busiest month. Other projects had no peak hour information, but only ADT projections[10]. Other projects gave peak hour projections for the a.m. only, ignoring the p.m. peak[11].

The major problems I encountered, however, were a result of Caltrans' District 4's (Bay Area) troubled traffic count program. Over the last decade the program has been understaffed, underfunded, and its information undervalued. While recently this trend has been partially reversed, the office is still low on hardware and skilled staff. California's traffic census

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[8] Personal communications with Emory Stoker, Research Analyst, Traffic Engineering Branch, Caltrans Headquarters, Sacramento; August 1990.

[9] (FEIS, Roseville Bypass, 9/84).

[10] (ND/FONSI, Proposed Widening of 152 in Santa Clara County, 4/87).

[11] (FEIS, Route 101 in Santa Clara County; [new alignment freeway from] Cochrane Rd....to 82. 7/78; ND, Widening 101 ...in Santa Clara County from the Lawrence Expressway to the San Mateo County Line, 10/86).

program calls for at least a third of the state highways and interstates to be counted each year. Thus the allowed maximum time between counts on a roadway is three years. In District 4, during the last decade these requirements were rarely met. Often traffic on a road went uncounted for 5 or more years.

The lack of up-to-date traffic counts created problems when trying to match a prediction to a count. Predictions are always made for a year at least 20 years in the future, and on some projects for intermediate years also, often at 5 or 10 year intervals. Growth (or decline) in freeway traffic volumes is not always linear, but is often exponential or logarithmic. Thus, in the typical case when the traffic was counted in a year for which there was no projection, simply interpolating the accuracy of the prediction based on straight-line traffic increases between the present and the predicted year(s) is somewhat inaccurate.

Furthermore, the census program calls for the highway under study to be counted for a period of at least a week in each of the quarters of the year. Unfortunately, some of the District 4 traffic counts were less than one week, and some were as short as 3 1/2 days. On most urban freeways and ramps, traffic varies substantially throughout the week, typically with highest volumes on Friday and other weekdays, and a marked drop in Saturday and especially Sunday traffic. In all cases where counts were made for less than a full week, the number of days is noted in the following Tables of results. The ADT figures I calculated from these short counts were <u>not</u> straight averages of the daily

traffic totals, but were adjusted using knowledge of weekly variations on adjacent ramps and freeway sections to provide a best estimate of an accurate ADT volume. Similarly, for counts of more than 7 days, the ADT's given are not a straight average of daily traffic totals, but are averages of the averaged weekday totals.

Traffic volumes fluctuate not only with the day of the week, but also by the season. While seasonal fluctuation is generally less on urban as opposed to rural roads, in California with our emphasis on recreation, urban seasonal variations are still significant. These variations are usually not recorded in the Bay Area, though, since the counts are made only once in the year of the count.

Another major obstacle to comparing predictions with counts was that even if the predictions were fairly extensive, frequently count information was available for only a small portion of the project. Basing a decision on the accuracy of an entire project's traffic predictions on the validity of a small portion's (e.g., one interchange) prediction is risky business. As seen in the findings discussed below, on many of the projects some predictions seemed reasonable while others were inaccurate. On one project, the only portions to be counted were those for which no predictions had been made[12].

Another problem in the data arises from the fact that

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[12] (DEIS, 92 Gap Closure and 92/101 Interchange Completion [in San Mateo County], 2/79).

traffic on freeway ramps is counted with rubber air hose counters, instead of wire loops buried in the roadway. The loops record passing vehicles. However the air hoses count axles, not vehicles, and record 2 axles as 1 vehicle. Therefore each truck, which has up to 5 axles, incorrectly triggers the ramp hose counter into thinking that 2.5 vehicles have passed. There is no separate or additional tally of truck traffic on ramps. Thus, the ramp volumes in the data actually overstate the number of vehicles. Of course, if the percentage of ramp traffic that is trucks is very low, this problem is minimized.

However, I chose not to use some arbitrary truck percentage to adjust the ramp volumes down, because of other problems that cause these figures to be too low. Measuring only one week out of the year and recording the highest observed volumes as the peak hour volumes is inaccurate. This is because the actual peak hour volume is the volume recorded if the highway were to be continuously monitored for an entire year and the tenth highest volume was selected. If the volumes were randomly distributed, the highest volume in a week of counting would be only 28% of the actual peak hour volume[13].

However, peak hour volumes are not randomly distributed,

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[13] Actual peak hour = $\frac{\text{10th highest hour}}{\text{8670 hrs. each year}}$ and 240 hours in 10 days. So observed peak hour is x of actual peak hour, where: $\frac{10}{8670} = \frac{x}{240}$ x=.28

because freeways have a finite carrying capacity. While the peak hour volumes I use as actual volumes are certainly more than 28% of the real peak hour figures, they are still probably underestimates. Thus this error tends to counteract the effect of not adjusting ramp counts downward to account for the presence of trucks on the ramp.

C. Findings

Because of the reasons described above, it was possible to include only 5 of the 27 projects in Part II of this study. Four were located in the Bay Area, and one was in the greater Sacramento region. Figures 1 and 2 show the location of the projects.

The first project was on I-680 in eastern Contra Costa County. In 1985, a new interchange at Bollinger Canyon Road was added to the freeway, and two existing interchanges, at Crow Canyon and Sycamore Valley Roads, were expanded. The FONSI/ND prepared in 1983 predicted traffic levels on all the ramps for the year 2005. (See Figure 3 for diagrams of all the ramps). In late April and early May of 1986, Caltrans crews counted traffic volumes on all the ramps, with their data collection varying from 10 to 3 1/2 days for different ramps. The 1986 ADT, and a.m. and p.m. peak hour volume counts are compared with the 2005 projections in Table 2.

For these three interchanges, there was a total of 18 ramps. For 11 of these ramps, the 1986 volumes were significantly less

Figure 1: Greater Bay Area Capacity Increases included in Part II

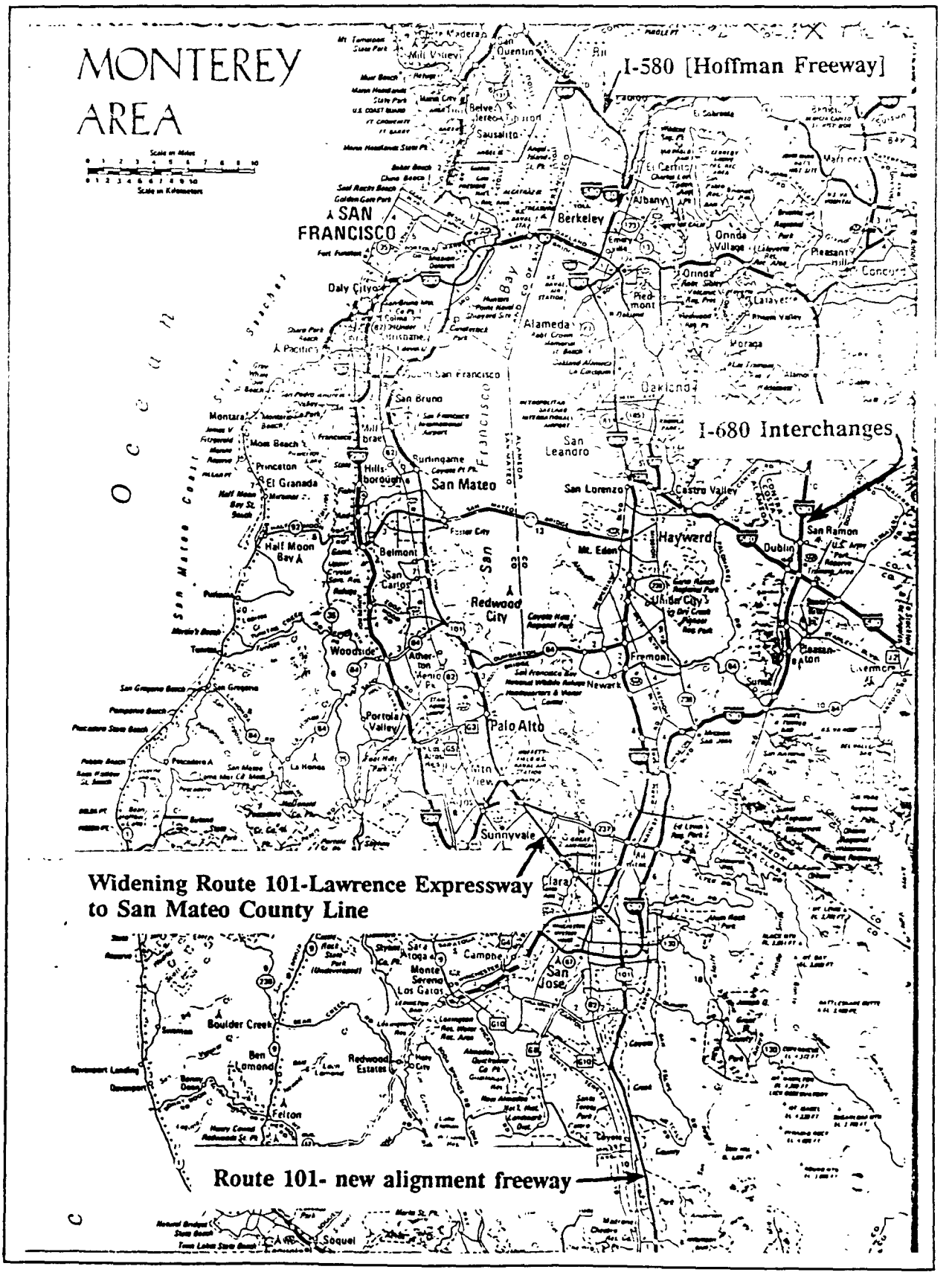

Figure 2: Sacramento Area Capacity Increase included in Part II

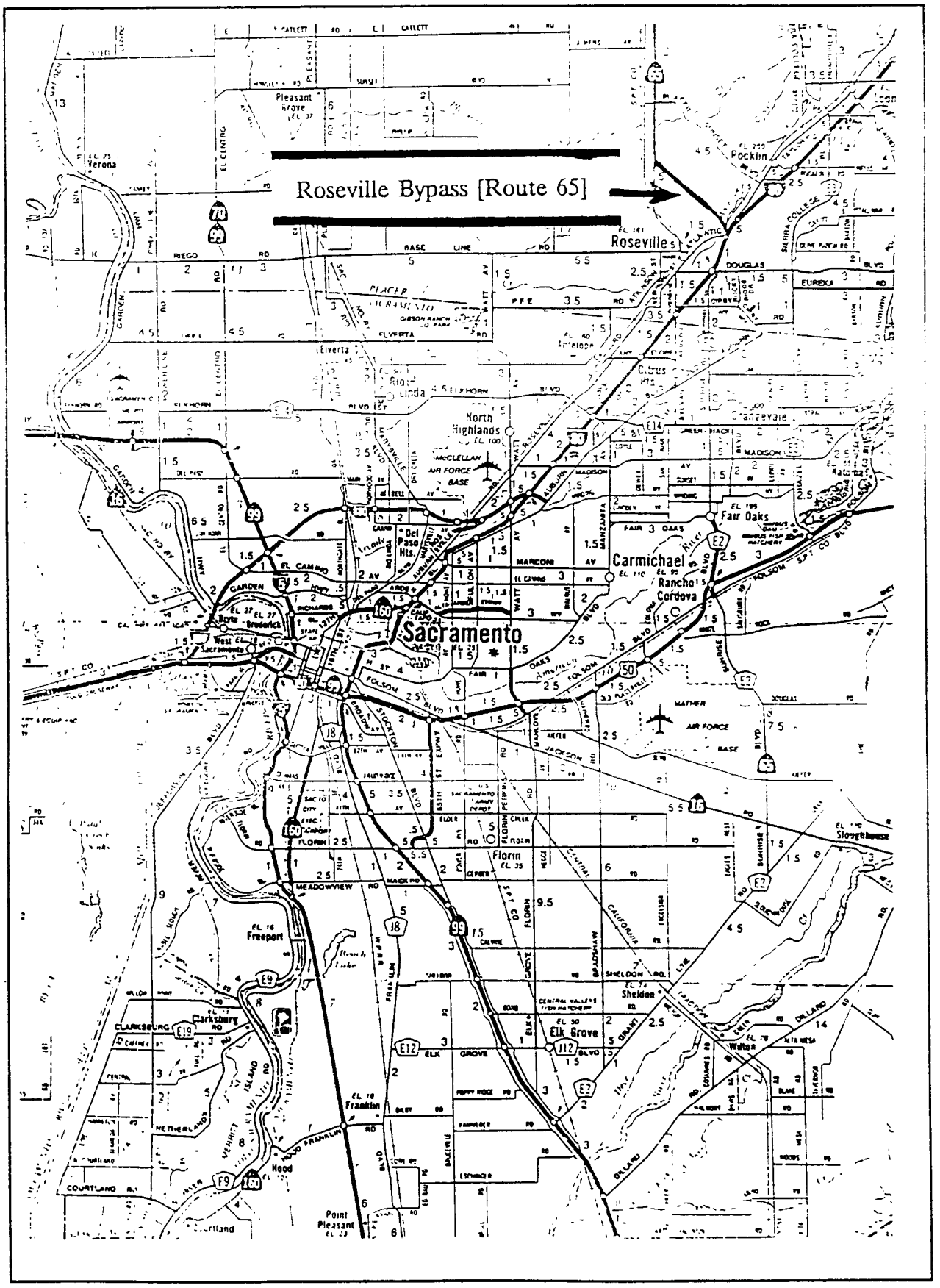

Figure 3: Ramp Configurations for I-680 Interchanges

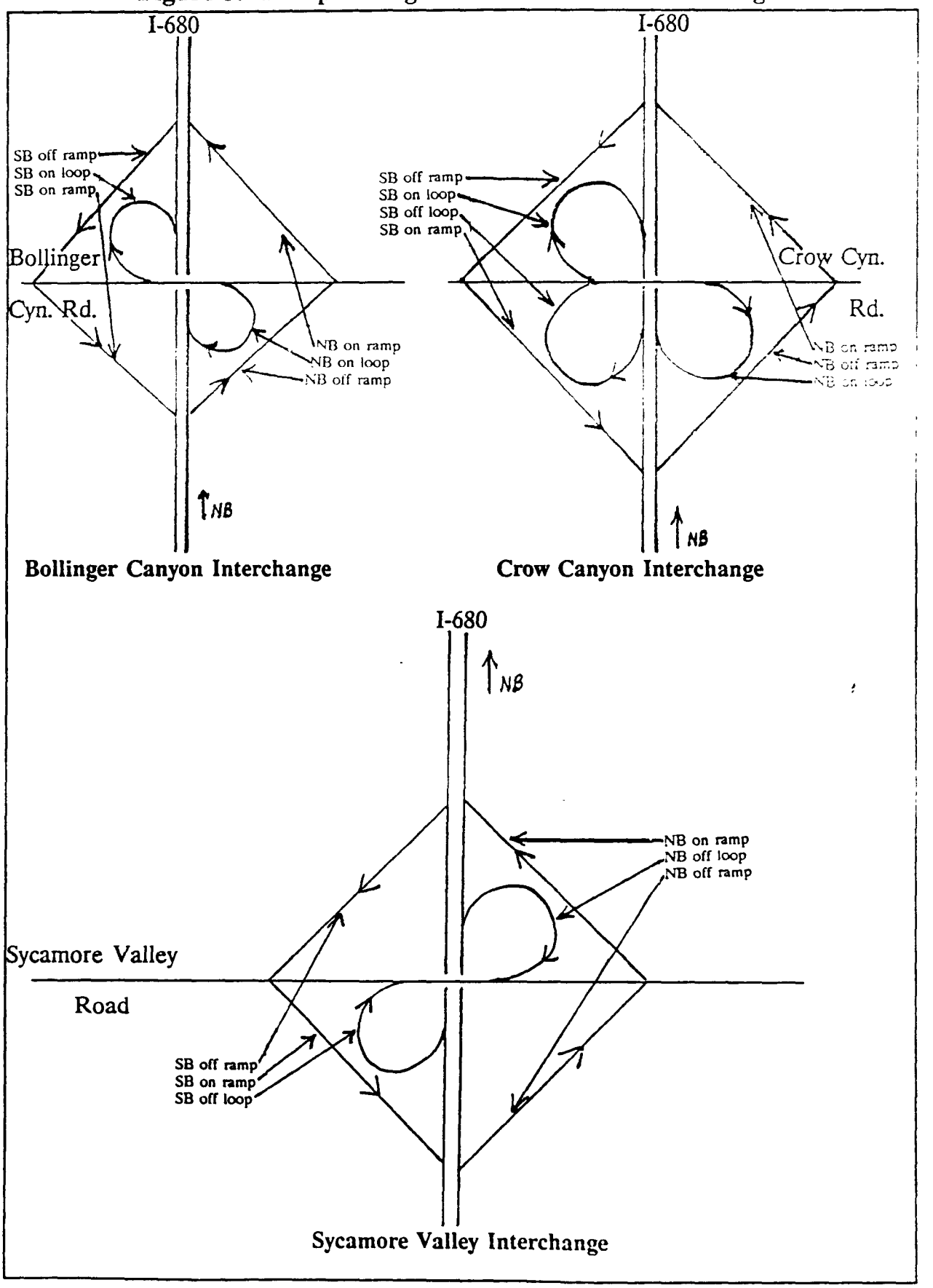

Table 2: Predicted and Observed Traffic Volumes on 3 I-680 Interchanges

Note: Predicted volumes are for the year 2005, and observed volumes are from counts in April and May of 1986. Ramp configurations are shown in Figure 3. North and southbound are abbreviated NB and SB, respectively. Interchange is abbreviated I/C.

	ADT		a.m. peak hour		p.m. peak hour	
Ramp	Observed 1986	Predicted 2005	Observed 1986	Predicted 2005	Observed 1986	Predicted 2005
(Bollinger Cyn. I/C:)						
NB off ramp	5,890	18,950	1,435	2,285	714	1,505
NB on loop[1]	2,186	1,850	488	130	189	240
NB on ramp[2]	4,045	12,325	239	650	895	1,315
SB off ramp	5,458	15,175	1,097	2,010	622	1,025
SB on loop[2]	3,296	15,500	373	1,250	1,056	1,850
SB on ramp[1]	2,275	2,320	322	250	233	260
(Crow Canyon I/C:)						
NB on loop	9,038	15,350	840	1,315	1,074	1,755
NB off ramp[2]	3,686	20,175	577	2,270	521	1,765
NB on ramp[2]	7,054	15,625	432	1,760	1,078	1,365
SB off ramp[2] plus off loop	16,880	29,525	2,344	2,640	1,383	3,265
SB on loop[2]	3,105	13,175	245	1,200	394	1,435
SB on ramp[1]	5,976	6,775	491	535	770	820
(Sycamore Valley Rd. I/C:)						
NB off ramp[1,2]	3,180	2,520	209	250	304	275
NB off loop[1,2]	3,682	3,990	387	245	353	440
NB on ramp[2]	9,803	18,060	1,135	1,420	880	1,985
SB off ramp[1,2]	4,534	3,890	367	995	415	430
SB off loop[2]	6,313	9,770	358	995	717	1,075
SB on ramp[1,2]	7,226	4,510	672	715	672	495

[1] indicates a ramp with a significant underprediction for one or more parameters.
[2] indicates a ramp where the observed ADT is an estimate based on less than a full week of traffic counting.

than the 2005 projections, typically ranging from a third to two-thirds of the 2005 projections. Because of the 19-year discrepancy between the counts and the forecast, this range of observed traffic levels seems reasonable. For at least one of the three parameters of ADT or a.m. or p.m. peak hour, traffic on 7 of the ramps in 1986 was higher than that predicted for 2005. Another of the ramps had 1986 volumes that were as high as 94% of the year 2005 predictions. These ramps are indicated in Table 2, and are distributed across each of the three interchanges. Caltrans seriously underestimated the future traffic volumes for these ramps, since traffic modeling shows yearly increases in traffic levels until the ramps or freeways are saturated, and then constant levels.

In 1984, 12 miles of new-alignment freeway opened in Santa Clara County from Cochrane Road in Morgan Hill to Route 82 in San Jose. The new freeway, part of Route 101, replaced a length of signalized highway known as Monterey Road and linked existing freeway sections to the north and south. The 1978 FEIS predicted 1995 AADT and a.m. peak hour mainline traffic volumes at 2 points along the new freeway. Two complete sets of these predictions were made for two different population projections. The "losouth" predictions assumed a moderate rate of growth in southern Santa Clara county, while the "grosouth" predictions assumed accelerated, substantial growth. Unfortunately, no predictions were made for ramp or p.m. peak hour volumes, and the AADT figures are 2-way volumes (lumping both travel directions

into the given volume).

Both the north and southbound directions of the new freeway between the Bernal and Cochrane Roads interchanges (the southern half of the project) were counted for 6 1/2 days in August of 1985. For the northern half of the new freeway, only the southbound direction was counted, in both April of 1985 and October of 1984 for 7 days each time.

Table 3 lists the traffic forecasts and the actual counts. Assuming that traffic volumes will not decline, Caltrans substantially underpredicted both AADT and peak hour traffic on this project. Virtually all the predictions for 1995 using either growth alternative were exceeded a decade early.

Another project on Route 101 further north in Santa Clara County widened the existing freeway from 6 to 8 lanes through the towns of San Mateo, Mountain View, and Palo Alto. Completed in December of 1988, this project had peak hour predictions for 1995 and 2010 for all ramps and sections of the mainline. These predictions were made by DKS Associates[14]. Unfortunately, only one of the numerous interchanges along this section of freeway had been counted since the project was completed, and none of the freeway mainline had been counted since it was widened.

The interchange that had been counted, in April of 1989, is the Lawrence Expressway/Route 101 interchange at the southern terminus of the project. The ramp configuration and designations

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[14] (July 1987 Route 101 in Santa Clara County: Bernal Road to the San Mateo County Line. Corridor Study and Operations Analysis, Final Report, DKS Associates).

Table 3: Predicted and Observed Traffic Volumes on Route 101 (new alignment freeway from Cochrane Road to Route 82)

Note: All predicted volumes are for 1995. North and southbound are abbreviated NB and SB. "GroSouth" assumes high, accelerated population growth in southern Santa Clara County; "LoSouth" assumes steady, continuing population growth.

Mainline south of Metcalf Rd. overcrossing (between Bernal and Cochrane interchanges):

"LoSouth" traffic predictions:

Two-way ADT:	NB a.m. peak hour:	SB a.m. peak hour:
45,000	2,420	1,620

"GroSouth" traffic predictions:

Two-way ADT:	NB a.m. peak hour:	SB a.m. peak hour:
56,000	2,970	1,980

Observed traffic volumes (based on a 6 1/2-day count 8/85):

Two-way ADT:	NB a.m. peak hour:	SB a.m. peak hour:
68,201	2,722	2,623

Mainline south of Blossom Hill Rd. (between Blossom Hill and Bernal interchanges):

"LoSouth" traffic predictions:

Two-way ADT:	SB a.m. peak hour:
54,200	1,950

"GroSouth" traffic predictions:

Two-way ADT:	SB a.m. peak hour:
67,200	2,420

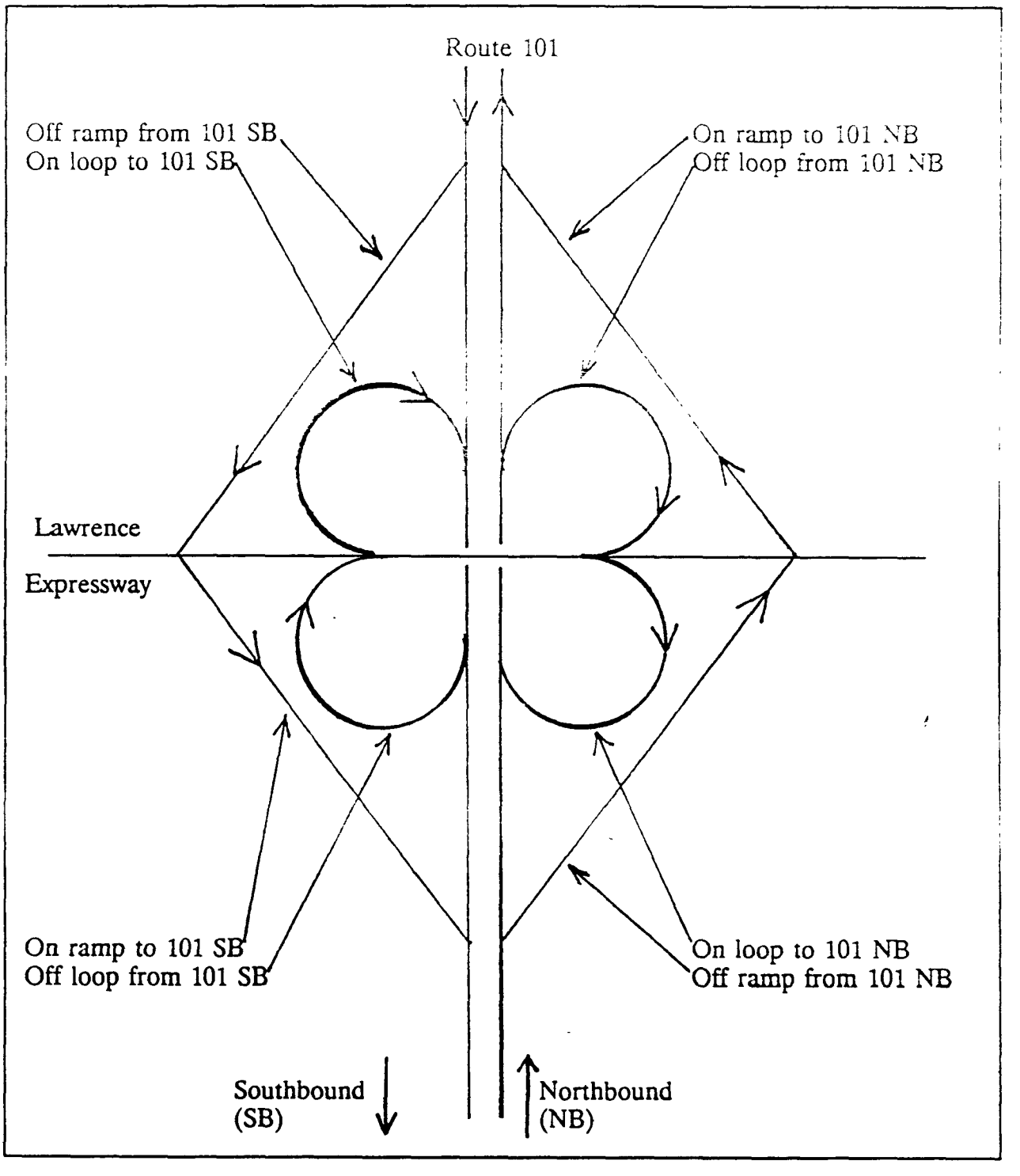
Observed traffic volumes (SB counts only; no NB counts):

(10/84)	SB ADT: 44,142	SB a.m. peak: 2,980
(4/85)	SB ADT: 36,576	SB a.m. peak: 3,034
SB average ADT: 40,359		average SB a.m. peak: 3,007

Two-way ADT:
80,718[1]

[1](calculated assuming SB ADT=NB ADT; actual two-way ADT may be greater since for mainline segment to the north, SB ADT was less than NB ADT)

Figure 4: Lawrence Expressway/Route 101 Interchange Ramp Configuration



of this full cloverleaf are shown in Figure 4.

Of the 8 ramps, 4 had 1989 a.m. peak hour volumes higher than the 1995 predictions, and 2 of these were even higher than the 2010 predictions. The comparison is shown in Table 4. While it was only possible to judge the validity of the forecasts for one of many intersections and nowhere on the mainline, and no forecasts were made for ADT volumes, fully half of the comparisons possible show substantial underprediction.

Table 4: Predicted and Observed Traffic Volumes for the Route 101/Lawrence Expressway Interchange

Note: Predicted volumes are for 1995 and 2010, and observed volumes are from April 1989 counts. Ramp configuration is shown in Figure 4. North and southbound are abbreviated NB and SB, respectively.

Ramp:	a.m. peak hour: 1989 (Observed)	1995 Prediction	2010 Prediction
On loop to 101 SB from Xway	334	539	651
Off ramp from 101 SB to Xway[1]	701	693	771
Off loop from 101 SB to Xway[1]	344	328	371
On ramp to 101 SB from Xway	798	1,050	1,000
On ramp to 101 NB from Xway	392	590	619
Off loop from 101 NB to Xway[1]	1,025	842	900
On loop to 101 NB from Xway	532	649	691
Off ramp from 101 NB to Xway[1]	722	674	720

[1] indicates a ramp where traffic was significantly underpredicted.

The fourth and final Bay Area project in this segment of the study was the construction of a new freeway from Route 80 to the Richmond/San Rafael bridge. The 6-lane freeway, with an HOV lane in both directions for much of its length, replaced a road network that consisted of both a signalized highway and a limited

access 4-lane expressway (Hoffman Boulevard). Original plans were for the freeway to be labelled Route 17 or I-180, but today it is designated I-580, although it is not yet complete. The road is open to traffic, but a few interchanges are not yet in their final configuration or are still closed. Caltrans officials believe that current traffic volumes are below the volumes the road will carry when it is completed.

Detailed predictions for 1995 ramp and mainline ADT and a.m. and p.m. peak hour volumes were made in the August 1979 Revised Traffic Projections for the 180 (17) Corridor... in the City of Richmond. Caltrans counted traffic on most of the existing on and off ramps in late April and May of 1990, but has not counted mainline volumes on the freeway. Indeed, counting the mainline will prove difficult, for in the rush to open the new lanes after the Loma Prieta earthquake of October 1989, no loops were installed.

However, because the bridge at the western end of the project is a toll bridge, daily traffic volumes are always recorded there. Thus ADT is readily calculable, but only in the direction of the toll, which is westbound. Knowing the total vehicles at the project's western terminus and adding and subtracting all vehicles entering and leaving the mainline could theoretically yield mainline ADT volumes at any point along the project. This was not possible, however, since Caltrans had not counted the exit immediately east of the bridge, among others.

Table 5 compares the 1995 predictions to the 1990 counts.

Table 5: Predicted and Observed Traffic Volumes on I-580 [the Hoffman Freeway]

Note: Predicted volumes are for 1995, and assume the freeway is completed. Observed volumes are from counts in late April and early May of 1990, when the freeway was not yet completed. West and eastbound are abbreviated WB and EB, respectively.

Ramp	ADT: Observed 1990	ADT: Predicted 1995	a.m. peak hour: Observed 1990	a.m. peak hour: Predicted 1995	p.m. peak hour: Observed 1990	p.m. peak hour: Predicted 1995
WB on ramp from Central Ave.[1]	4,458	2,940	378	260	511	140
EB off ramp to Central Ave.	2,380	2,625	193	210	236	345
WB off ramp to Bayview Ave.[1]	3,564	5,400	200	490	711	320
WB on ramp from Bayview Ave.	1,904	5,870	180	495	182	370
EB on ramp from Bayview Ave.[1]	2,039	5,400	407	300	183	325
WB off ramp to Erlandson St.	2,288	7,000	187	400	235	600
EB on loop from Erlandson St.	1,801	7,000	123	500	222	360
WB off ramp to 23rd St.[1]	5,506	7,860	316	480	599	430
EB on ramp from 23rd St.[1]	2,322	3,950	372	100	226	310
EB off ramp to 23rd St.	1,649	4,670	128	275	191	470
EB on loop from 23rd St.[1]	3,937	4,320	884	300	244	290
WB off ramp to Harbour Way[1]	3,109	5,055	213	170	435	320
WB off ramp to Cutting Blvd.[1]	2,358	2,405	271	250	214	160
EB off ramp to Cutting Blvd.	4,233	8,600	310	565	422	770
EB off ramp to Marine St.	3,723	5,600	443	935	502	590

Observed toll plaza WB mainline ADT: 24,893
Predicted WB ADT for mainline 580 east of Western Dr. interchange: 30,000
(see text for discussion of mainline comparison)

[1] indicates a ramp with a significant underprediction for one or more parameters, although some of the other ramps may also represent underpredictions.

Of the 15 interchange ramps on this section of I-580 that could be included in the study, 8 had actual traffic volumes that exceeded predicted volumes for ADT or a.m. or p.m. peak hours. These ramps are indicated in the table. Only one of these ramps had all three parameters exceeded; the other 7 had one or both peak hour predictions exceeded. Additionally, various other ramp volumes were close to the level forecast for 1995.

There was no ADT prediction for the freeway at the toll plaza, but there was a prediction one interchange to the east of the toll. This interchange, Western Drive, is estimated by

Caltrans District 10 traffic count staff to carry relatively minor levels of traffic, and thus the ADT mainline predictions just east of Western Drive can be used as roughly equivalent to the ADT predictions at the toll plaza. Table 5 also compares the toll plaza ADT count based on the late April and May traffic to the mainline prediction east of Western Drive. While District 10 traffic count staff suspect that west and eastbound ADT volumes are not equal on I-580, since the toll is only collected in the westbound direction, there is no measurement of eastbound traffic. Thus I could only compare the observed westbound ADT volume at this point to the westbound prediction to the east. This prediction seems reasonable, for the 1990 traffic is considerably below the level projected for 1995.

Of the 6 projects in the greater Sacramento area, it was possible to include only one, the Roseville Bypass, in this second part of the study. In September of 1987, a new-alignment, 4-lane limited access expressway opened from the existing Route 65 to I-80, allowing through traffic to bypass the signalized highway through downtown Roseville (see Figure 2). This bypass is essentially a new-alignment freeway. Predictions of 2-way ADT and peak hour volumes on the bypass were made in the 1984 FEIS for traffic levels in the year 1987 and at 3-year intervals thereafter. Traffic on the bypass is counted continuously, and Table 6 compares the predictions to the counts.

The actual volumes are less than the predictions for this project. Roseville was predicted to develop substantially as the

Table 6: Predicted and Actual Traffic Volumes on the Roseville Bypass (Route 65)

Note: Actual volumes are rounded to the nearest hundred. Actual ADT volumes are AADT figures; predictions are not assumed to be AADT figures. Actual volumes were obtained for a continuous count of the freeway for the entire year specified.

Two-way mainline ADT volumes:

1988 Actual	1989 Actual	1987 Prediction	1990 Prediction
13,000	14,800	11,700	21,200

Two-way peak hour volumes:

1988 Actual	1989 Actual	1987 Prediction	1990 Prediction
1,300	1,500	1,300	2,200

computer and semiconductor industries moved to the area. One factor that may explain the lower than expected volumes is that as a result of changes in these industries much of the predicted development has not occurred.

D. Discussion of Part II Findings

Despite the numerous problems and uncertainties discussed at length earlier with the data this study uses, it is clear that the planning for freeway capacity increases has frequently underestimated the traffic that actually uses the new or improved roads or interchanges. While the magnitude of the underprediction has varied, in 5 of the 6 projects that were analyzed, the forecasted traffic volumes or some portion thereof were exceeded, as much as a decade ahead of schedule. Thus it seems that there has been a consistent underprediction of traffic use for a variety of projects, including those planned quite recently as well as more than a decade ago.

Looking in detail at the specific factors that could explain where the forecast models erred is beyond the scope of this study. Certainly one problem is the lengthy time between project planning and construction. Because of the complex environmental process, the vagaries of construction, political opposition, or inertia, planning and constructing a major freeway project can take up to a decade or more. This tends to decrease the validity of the forecast models for several reasons.

First, given infrequent traffic counts, the counts on the existing road network, which are an essential input to the models predicting future traffic, often predate the final environmental document by as much as 4 years. If traffic has increased during this time, which almost invariably is the situation in California, the models will tend to underpredict future traffic. Second, lengthy time between planning and construction may mean that the effects on traffic of significant increases or locational shifts in regional growth in the meantime are not predicted.

An "explanation" by Caltrans for the observed underpredictions might simply be that regional growth outstripped the projections of the various local and regional planning bodies, and blame for this is simply not attributable to the transportation providers. However, increased regional growth is often a function, at least in part, of freeway capacity increases.

Ultimately the reason for underprediction is irrelevant when

weighing the consequences of this trend on regional air quality. Because congestion levels and tailpipe emissions are partially determined by traffic volumes, underprediction of volumes means that these projects' air quality analyses were inaccurate and overly optimistic. No matter the cause, consistent underprediction of future traffic means that the supposed air quality benefits of freeway work have been consistently overstated.

CONCLUSION

This study found significant flaws in the air quality analyses done for freeway capacity increases. The level of detail of the analyses was often inadequate and the traffic forecasts underlying the analyses showed a pattern of underprediction of the improved roads' actual use. Freeway projects that were allowed on the belief that they were going to help solve our pollution problems have instead probably made them worse.

Checking on the accuracy of the traffic predictions is essential to preventing further deterioration in air quality. After years of federal and state reductions in highway project funds, Proposition 111, in addition to county transportation tax initiatives throughout the state, will provide a huge influx of money into cash-starved construction programs. Many projects which have been planned for years will now have their NEPA/CEQA documents prepared, or will be put out for bids. If traffic

predictions turn out to significantly understate the actual traffic levels on these projects, Californians will suffer by breathing air that will be more noxious than predicted in the projects' air quality analyses.

Furthermore, given the drastically tighter standards of the California Clean Air Act, as well as the forthcoming Clean Air Act amendments, it is now more important than ever to scrutinize these types of highway projects closely to see that they don't pull our urban areas into a smog-choked future from which we could only escape at enormous social cost.

To improve the planning process for these types of projects, I suggest the following steps be undertaken. Most urgently, Caltrans should improve its traffic counting program, especially in the Bay Area and other areas of the state where this program is weak. Spending over a billion dollars a year on construction and so little on traffic counts is poor public policy, for the counts form the basis on which all highway planning rests.

The technology exists, and is employed in the Sacramento area, to continuously count freeway traffic. For roughly $4,000 for each location, Sacramento has permanently installed the hardware needed in conjunction with buried roadway loops to continuously monitor freeway mainline and ramp volumes. Using loops to monitor ramp traffic, as is done in Sacramento, eliminates the inaccuracy of air hose counts caused by vehicles with more than 2 axles. Also, new loops have become available which are round in shape rather than square, and appear to be

considerably more reliable and less prone to failure. Broken loops should be replaced, and all new projects should have loops installed as a matter of course.

Predictions for traffic use on capacity increasing projects should be standardized to include estimates of AADT and a.m. and p.m. peak hour volumes, for each roadway direction, rather than minutes of delay, combined 2-way volumes, or other information. Even more importantly, Caltrans should check the accuracy of their traffic predictions by comparing them to actual roadway counts to continually improve predictions on future projects.

The analysis of the effect of the project on emissions should as a minimum quantify the emissions on CO (both in the immediate project vicinity as well as regionally), HC, NO_x, CO_2, and PM-10. A practical monitoring and compliance plan should be required to be a part of every project that alludes to mitigation measures. Interchange projects should model not only the emissions of the cars actually on the ramps or in the interchange, but also the emissions of the vehicles on the mainline affected by the interchange traffic.

Appendix A

There is a fairly large body of research that examines the effect of highways on regional economies and land use. With the large amounts of federal money provided for the interstate network in the 1950's and early 1960's, there was an accompanying flurry of academic research, as well as studies sponsored by the DOT and FHWA, on the effects of these highways. Much of this work falls into one or more of the following categories:

-The effect of a highway bypass on the economy of the bypassed town or village;

-The regional economic effects of urban beltways;

-Land use patterns at freeway interchanges in both rural and suburban areas;

-Highway impacts on both actual and perceived property values;

-Land use changes resulting from arterial and highway improvements, for both rural and for urban areas;

-Demographic and community changes resulting from new alignments and highway improvements.

These studies have used a very diverse assortment of data sources, including aerial photography, number of and prices for home sales, interviews with local officials and homeowners, census tract information, gross sales and manufacturing data, and county zoning maps.

Some of the more interesting or relevant studies are

summarized below. The call number, in parentheses, is used by the Institute of Transportation Studies Library, at UC Berkeley, where most of these are available.

Griggs, A.O. Review of Some Effects of Major Roads on Urban Communities. '83. Chapter 3, "Land Use Changes".
Includes summary of various studies done on the effect of house prices. Typically these show a slight decrease in value for houses very close to the freeway (a result of increased noise) and increases for those homes nearby that benefit from the improved mobility. Range is -6 to +10%. (NS 83-531).

Kingham, I.R. "Suburban Hwys. & Roads as Instruments of Land Use Change," Trans. Research Record 565, '76.
Highway engineers see their task as catching up on the provision of road capacity to meet travel demand. "Suburban highways are a result of land development and do not influence land use change." All he did to conclude this, though, was interviews; a study with limited use.

Buffington, J.L., et al. "Non-User Impacts of Different Hwy. Designs as Measured by Land Use and Land Value Changes. Research Report 225-2. Tx. Trans. Inst., Tx. A & M University. '78.
Found (for Texas) that urban areas were less affected by highway improvements than suburban and rural areas, because of the lack of undeveloped properties to develop.

Adkins, W.G. & A.W. Tieken. "Economic Impacts of Expressways in San Antonio, Tx. Trans. Inst., Bull.#11, '58.
Because of the lack of undeveloped/vacant land in the region, there were few land use changes when the new expressways were built.

Adkins, W.G. "Effects of the Dallas Central Expressway on Land Values and Land Use," Tx. Trans. Inst., Bull.#6, '57.
This freeway, built through a previous slum, created major land use changes. Much new commercial, industrial, and residential development occurred. Most of these changes occurred abutting the highway or not far from it, though.

Duke, R. "The Effects of a Depressed Expressway-- a Detroit Case Study," The Appraisal Journal,'58.
Ford Expressway influences limited to roughly 300 metres on both sides of it.

Palmquist,R.B. "The Impact of Hwy. Improvements on Property Values in WA State," for WA DOT. '81.
Multiple regression study shows appreciation for areas with the

new highway is 15-17% higher than for those without. Even within 600' of the road where noise is an issue, appreciation due to accessibility is generally greater than the noise depreciation. A sophisticated study: he looked at over 9000 sale prices, as well as interviewing residents. However, the increases in appreciation occurred only where the highway could be used for commuting. (TA1001.5.P7).

Yu,J.C.& Allison,J.L. "A Methodology for forecasting Beltroute Corridor Land Use Impacts and its Application to Utah I-215. Dpt. of Civil Eng., U. of Utah, '85.
Essentially the goal of this study is to allow towns to plan to encourage "appropriate" (as defined by each community) growth along the road corridor. The authors believe that beltways are developed differently than regular limited-access expressways, because they carry a different set of passengers. They establish a complex predictive model to be used by town planners across the country, who must input data specific to existing land uses in the region of their proposed beltway. They test their model on I-215 outside of Salt Lake. Conclusions: "[Beltroutes] are particularly capable of altering, on a large scale, the attitude potential land users have for land within the region through which the route will be located as well as for land within reasonable distance of the beltroute." "The perpendicular extent of the [beltroute] corridor is a function of the homogeny of land use as well as homogeny of characteristics of the land itself. The extent [of] such a homogeny, both perpendicular and parallel to the beltroute, yields an indication of the potential area that a particular land use may eventually occupy." "A beltroute can facilitate and even precipitate new land uses within the urban area..." (TA1001.5.P7).

Payne-Maxie Consultants, Blayney-Dyett Urban & Regional Planners. "The Land Use and Development Impacts of Beltways: Case Studies," for DOT, '80.
A huge study trying to pin down the effects of urban circumferential highways for 8 regions. Most of the roads studied were built in the '60's or '70's. It lacks any statistical techniques to attempt to accurately link changes to the road, but rather tries to do so anecdotally/qualitatively. 200 pages later, the reader has a picture of how areas develop, but not how the roads affected their development. (HE370.2.P2).

Barton-Aschman Assoc., for Illinois DOT. Highway and Land-use Relationships in Interchange Areas, Springfield, VA. '68
A fairly typical example from numerous studies I saw on land use at interchanges. (There is a related set of research on the economics of interchange location, typically in terms of sales volumes, based on such factors as ADT on the highway). This study concludes "new hwy. facilities have a strong tendency to generate new uses of land that are often, themselves, generators

of large traffic volumes" [e.g., shopping malls]. (HE370.2.B2).

Babcock,W.F.& Khasnabis,S. "An Analysis of the Impact of Freeways on Urban Land Developments in NC...," NC State Raleigh, '74. "Historically, the estimation of traffic for the freeway & the intersecting roads has been accomplished by standard traffic projection techniques. Generally, these have been based upon existing land development plans and adopted transportation plans. In many cases, such predictions have not been realistic, because of unanticipated traffic that was generated by new land uses brought about by the existence of the freeway." This study tried to determine what development had occurred because of the freeway by looking at aerial photographs over time and interviewing city planners. (4505 Microfiche).

Burkhardt,J.E. Socio-economic Reactions to Hwy. Development, '83. Analyzes effects of freeways typically built through urban, and usually poor, areas in the 1960's & 1970's. He looked at demographic, land use, housing market, etc. changes.
While such freeway building has essentially stopped today because such projects are no longer socially acceptable, he has some interesting findings. Measurable impacts were limited to a 5 to 10 block swathe adjacent to highway, and the impacts were not necessarily negative for the neighborhood. Big conclusion: the general patterns of these freeways on the adjacent areas are definitely secondary to site-by-site variations. (TA1001.5P7).

Cosby,P.J.& J.L.Buffington OR Herndon,C.W.& Buffington. "Land Use Impacts of improving... Collins St. in a Developed Area of Arlington, TX/ Gessner Rd. in a Developing Area of Houston/ etc. Tx. Trans. Inst., Tx. A&M U., Ntl. Tech. Info. Service. '79 to '80.
These are 6 very similar studies which use the same research methodology. All look at improvements to arterial [non-expressway] roads in different urban and suburban areas of Texas. The studies set up 6 categories of land use, and quantify the changes in land use occurring after the road upgrades. Typical conclusions: "although the improvement of Collins St. helped create an area more attractive for development, the impact on land use [for this developed area] was not extensive. a). Most of the development in this area occurred... before the road improvement began and was most likely not influenced by the road change....c) The road improvement is viewed as a positive influence, because if the street had not been widened the resulting congestion would have been a deterrent to development. OR: [for a developing area], 1)Commercial and multi-family residential developments that were put on unimproved land were located in the Gessner area partly because of the improved access. 2). The improvement was also important in the changes from single family to commercial and multi-family uses. General criticisms: These studies are fairly simplistic. By lumping all

land use into 6 categories, they do not distinguish between density, quality, etc. of the areas before and after improvements. Furthermore, they limited analysis to what struck me as an overly-narrow band along the improved roadways. There is no attempt to verify causality of changes, but only the assumption that the changes are a direct result of the road. Finally, none of the studies looked at limited-access highways. (N.S.79-998,80-404/5/6.etc).

Rollins,J.B. et al. Effects of Roadway Improvements on Adjacent Land Use: An Aggregative Analysis and the Feasibility of using Urban Development Models. Tx. Trans. Inst. in coop. with FHWA. Research Report 225-22. Study 2-8-77-225. '82
This study looked at 18 arterial improvements in non-rural Texas, including the ones above. Typical improvements were arterial lane increases, adding medians, turning lanes, etc., and most were done in the '70's. This was easily the most statistically sophisticated study I found. Techniques included ordinary least squares multiple regression and a simultaneous equations model with two-stage and three-stage least squares. The model allowed the changes in the percent of each of the 6 land use categories to be explained by numerous other independent variables besides just the road improvements. Conclusions: net overall land development is not significantly changed due to the roadway improvements. But, roadway improvements do affect the development rates of specific types of land uses. Residential and public development are associated with ADT growth, and thus road improvements. (N.S.82-116).

Economic and Social Effects of Highway Improvements, Section IV, "Land & Prop. Values & Land Usage in relation to Dort Hwy. improvements. U.Mich., '61.
Older study, but some interesting findings. "The Dort Highway [a Flint, MI bypass built in the late 1950's], like most other major arteries, has been a powerful force molding & developing the area which it serves." "The highway, by providing accessibility, makes it possible to subdivide large tracts for the more intensive uses demanded as a result of increasing economic activity and growth..."

Mountain West, Socioeconomic and Land Value Impact of Urban Freeways in Arizona, for AZDOT in coop. with FHWA. (FHWA #AZ87-282). '87.
Very thorough, careful study of the impact of freeway construction on land use changes and property values in the greater Phoenix region. To study land uses, aerial photography, zoning changes, census data, and planning documents were used. Property sales and valuation data and owner interviews were also used. This study used control areas (lacking the freeways but otherwise similar) to link observed changes specifically to the freeways. Major findings: "The strongest and most obvious conclusion about the historic

socioeconomic impact of freeways in metro Phoenix is that freeways are a necessary but not sufficient cause for development to occur. Other factors are equally as important, including municipal planning and zoning, land availability, existing utilities and infrastructure, and other transportation modes-- railroads and arterials... (etc). Freeways merely create a condition that improves the market opportunity for change.... Development around freeways can be controlled by strong urban land use planning. However, it is clear that income-generating properties-- non-residential uses and apartments-- have strong locational preferences for freeway corridors... [The] intensity of freeway corridor development depends on a combination of macroeconomic demand conditions and the supply of developable land... Beyond these broad statements, the specific kinds of land uses and their locations are very much dependent on the peculiarities of place-- existing land uses, existing zoning, etc... Land values in proposed freeway corridors have increased due to road alignment announcements... It is clear that freeways have stimulated non-residential growth."
This grossly oversimplifies very detailed findings.
(HE336.E3.T66).

Briggs,R. "The Impact of Interstate Hwy System on Non-metro. Growth," DOT, Office of Univ. Research. Ntl. Tech. Info. Service, '80.
Statistically sophisticated look at the big national picture; included suburban, exurban, and rural growth across the country. The county was the unit of analysis. Conclusions: "The results of the research showed that, while counties with Interstates... have higher average growth rates, even after confounding factors... are controlled, the presence of a limited access highway is far from an assurance of development for an individual county... The Interstate system was <u>less</u> able to explain the spatial pattern of development than non-transportation factors.
(PB81-212987 fiche).

Few studies investigate the effect of highway improvements on induced trips/ADT/congestion, and thus air quality. All too often this topic is discussed in general qualitative terms with apparently very little quantitative work having been done to demonstrate actual effects. The following studies touch on this issue at least peripherally.

John Paterson Urban Systems. Feasibility of Assessing Effects of Road Improvements on Trip Making and Urban Public Transport. for the [Australian] Commonwealth Bureau of Roads, '71.
Essentially, this whole document is an attempt by a consultant to secure a contract to write a computer model to forecast the effect of highway improvements on induced trips. He wanted about Aust. $25,000 in 1973 money to do it, and predicted that it would take 3 people most of a year to write the model. Apparently he didn't get the contract. This document/proposal is very general and of limited use. (HE370.2.J6).

Ziering,E. et al. "Energy Impacts of Transportation System Improvements," Trans. Research Record 870.
This study basically applies modeling and work done by numerous other researchers into a new model. "Unlike many earlier energy impact estimation procedures, this methodology explicitly considers induced and diverted travel resulting from a transportation improvement and the effect of this travel on the level of transportation services." Key to calculating the induced traffic levels are a set of travel-demand elasticities developed by Charles River Associates for the CA Energy Commission in 1982. "[The model] produced results that were frequently counterintuitive... and contrary to commonly accepted conclusions [ie, road improvements conserve fuel by reducing congestion] concerning the energy [and air quality] impacts of projects." Furthermore, "Highway widening or bypass projects can either increase or decrease... consumption... Ramp-metering projects yield energy savings when implemented under congested conditions... In most cases, ramp delays reduce the amount of induced new travel."

"The Vehicle-Miles of Travel-Urban Highway Supply Relationship," in Ntl. Coop. Hwy. Research Program's Research Results Digest #127, 12/80.
Summary of NCHRP project 8-19 by Cambridge Systematics et al. which generated a computer model that relates highway supply to, among other things, air quality. This model, which apparently is huge and consumes large amounts of computer time, was run on 2 Bay Area highways: lane additions to Rte.24 from the Caldecott Tunnel east to Concord, and construction of Rte. 24 west from the tunnel. The model says both these projects have been net air quality improvements for all pollutants except for NOx. (TA1001.5.N32).