Title

Determining the Effectiveness of HOV Lanes

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Determining the Effectiveness of HOV Lanes

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Final Report for Task Order 5326/6326

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The research team members would also like to acknowledge and thank Dave Schumacher, Chair of the TRB Standing Committee on HOV Systems, for his support of this project.

ABSTRACT

This document is the final report for the two-year PATH Project "Determining the Effectiveness of HOV Lanes". It has been supported by the California Department of Transportation (Caltrans). The primary objectives of this project have been to evaluate freeways having on-freeway HOV lanes in terms of vehicle-travel, person-travel, occupancy distribution, shape and duration of the peak period, congestion patterns, and air quality both in the HOV lane and the adjacent mixed-flow lanes.

Based on a comprehensive literature review an extensive list of reference was developed, along with summaries synthesizing the state of the knowledge regarding the effectiveness of HOV lanes and their impact on air quality.

Historical and current field data were assembled and analyzed for all of California's HOV lanes. The analysis revealed that there is strong public support for HOV lanes, California's HOV lanes are well utilized and offer significant time savings to ride sharers, that there is a steady growth in the number of carpoolers, violation rates are low, and that over time, HOV lanes cause carpools to last longer.

The air quality module in the freeway simulation model FREQ was updated to reflect the most up-to-date techniques for predicting air quality developed by the California Air Resources Board in their EMFAC model. The new air quality methodology was also used to develop an off-line air quality module for use with PeMS data.

The design of a successful HOV lane facility is a very difficult task and requires careful analyses prior to implementation in order to move toward an optimum design. Accurate data on vehicle occupancy distributions and traffic demand levels are essential for realistic modeling of such facilities. To demonstrate the types of analyses that would be useful in this process, the modified freeway simulation model FREQ was applied to two freeway study sites, one in Northern California and one in Southern California. The FREQ model proved to be well suited for investigating various combinations of HOV lane design and operating parameters. As traffic demands increase and HOV lanes generate changes in ridesharing choices, the continued success of HOV lane operation is likely to require changes in HOV lane design and operations. This will require careful monitoring of the HOV lane facility and further modeling analyses.

Keywords: Computer Simulation, Emissions, Energy Consumption, Environmental Impact, Environmental Impacts, Evaluation Models, Freeways, High Occupancy Vehicle Lanes, Policy, Traffic Congestion, Traffic Control, Traffic Delay, Traffic Diversion, Traffic Flow, Traffic Demand Management, Travel Time

EXECUTIVE SUMMARY

This report describes the findings of a two-year investigation of the effectiveness of California's HOV lanes undertaken for Caltrans by researchers at the University of California at Berkeley as part of the California PATH Program. The investigation entailed a comprehensive literature review, a detailed examination of historical and current field data, the updating of air quality models, and the modeling of alternative design and operating options in Northern and Southern California.

LITERATURE REVIEW

At the beginning of this investigation, a comprehensive literature review was conducted. An extensive list of references was developed, along with summaries synthesizing the state of knowledge regarding the effectiveness of HOV lanes and their impact on air quality. Additional key references, which appeared in the literature after the initial search, were added during the project.

ANALYSIS OF OPERATING DATA

Historical and current field data were assembled on all of California's HOV lanes. Historical trends were analyzed, current operations were documented, past programs were investigated, operating personnel were interviewed, and public opinion polls were reviewed. This process led to the following key findings:

- **Strong Public Support**. Carpoolers and non-carpoolers alike understand and strongly support HOV lanes.

- **Good Utilization and Time Savings.** California's HOV lanes are well utilized during the peak periods and offer significant time savings to ride sharers, who realize an average savings of 6.7 minutes per trip.

- **Steady Growth.** It takes time for carpoolers to make and maintain ridesharing commitments. But in most cases on California's freeways, the introduction of HOV lanes has been followed by a gradual build-up of ridesharing and an increase in the life span of carpooling and vanpooling arrangements.

- **Carpool Composition.** Most carpoolers (roughly ninety percent) ride with family members or coworkers. While regular carpooling arrangements are most common, at any given time as many as 20% of the people in carpool lanes are infrequent users who share rides roughly once every other month.

- **Safety.** There is not enough evidence to state whether HOV lanes increase or decrease accidents when installed on mainline freeways. However, the installation of direct HOV-to-HOV connectors has almost universally reduced nearby accident rates.

- **Violation Rates**. Violation rates in all Caltrans districts average 5.6%, well below the ten percent level identified as a threshold for concern.

- **Do Measured Ridesharing Increases Reflect New or Diverted Carpools?** As time goes on, the question of whether the carpools added to the freeway mix were new or diverted becomes less and less important. If new, they represented an immediate improvement in the overall vehicle occupancy picture. If diverted, they filled space reserved to reward ridesharing behavior and freed up the space they left to relieve the congestion faced by non-carpoolers. Over time, there is evidence that the HOV lanes cause carpools to last longer, regardless of how they came to be in the lanes.

MODELING AIR QUALITY

The FREQ model was modified to reflect the most up-to-date techniques for predicting vehicle emissions developed by the California Air Resources Board in their EMFAC model. The updated methodology was developed, tested, and successfully demonstrated in a FREQ analysis of two California freeways and as an off-line module manipulating freeway performance data from surveillance detectors stored by PeMS (Performance Measurement System).

ALTERNATIVES ANALYSIS

The updated FREQ model was used to demonstrate the analysis of the following policy and design options on two California freeways under changing demand and ridesharing conditions:

- 3+ and 2+ carpool lane additions on I-580 in Northern California; and
- Limited HOV lane access on I-210 in Southern California.

3+ vs. 2+ Operating Policies. The addition of a 3+ HOV lane on I-580 under current demand conditions resulted in traffic flows of 300 to 350 vehicles per hour in the HOV lane, leaving considerable excess capacity for future growth. As demand and carpool levels increased, HOV lane utilization also increased, rising to 500-550 vehicles per hour, and congestion developed in the non-HOV lanes, raising the speed differential between HOV lanes and non-HOV lanes increased from 4 mph to 22 mph. The predicted results indicated a significant reduction in total travel time, an increase in vehicle-miles served, and no change in fuel consumptions rates nor vehicle emission rates.

If the occupancy requirements of the new HOV lane are changed to 2+, increases in demand quickly congest the HOV lanes, causing the speed differential between HOV and non-HOV lanes to drop. As a result, the "window of opportunity" when the system might benefit from the addition of a 2+ HOV lane was relatively small. This window opened when traffic demand was heavy and there were relatively low percentages of HOV vehicles, or when some 2+ vehicles decided not to use the HOV lane. The operation with a 2+ HOV lane implementation can likely be enhanced by introducing intermittent HOV lane barrier(s).

Intermittent HOV Lane Barrier Design. The quality of freeway performance with the existing intermittent HOV lane barrier design depended upon the vehicle occupancy distribution and unfortunately accurate data was not available. The best 'window of success' occurred with relative low percentage of 2+ vehicles (4% to 12%). Under higher percentages of 2+ vehicles, the HOV lane was predicted to be congested.

In an attempt to extend the 'window of success' to higher 2+ vehicle percentages, the existing intermittent HOV lane barrier design was modified by reducing the number of access/egress

points to the HOV lane. This more restricted intermittent HOV lane barrier design marginally increased the ‘window of success’ to higher 2+ vehicle percentages.

Analytic Conclusions. The design of a successful HOV lane facility is a very difficult task and requires careful analyses prior to implementation in order to move toward an optimum design. Accurate data on vehicle occupancy distributions and traffic demand levels are essential for the realistic modeling of such facilities. As traffic demands increase and HOV lanes generate changes in ridesharing choices, the continued success of HOV lane operations is likely to require changes in HOV lane design and operations. This will require careful monitoring of the HOV lane facility and further modeling analyses. The FREQ model proved to be well suited for investigating various combinations of HOV lane design and operating parameters.

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CHAPTER ONE

INTRODUCTION

1.1 OVERVIEW

The implementation of freeway HOV lanes has been a controversial issue since the 1970's with the Santa Monica freeway experience and continues today. While the implementation of freeway HOV lane mileage has grown, the controversy continues, particularly from the public and environmentalists, partly due to incomplete assessments, and, perhaps in some situations, to questionably implemented sites. This applied research project provides factual evidence of the effectiveness of existing HOV freeway facilities based on field data and delivers methodologies for predicting the effectiveness of existing and proposed HOV freeway facilities from the perspectives of both freeway performance and air quality.

1.2 RESEARCH PLAN

Six tasks were defined to accomplish the goals of this project.

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Task 1: Comprehensive Literature Review and Synthesis of Current Knowledge

An extensive literature search was undertaken using the University of California, CALTRANS, Transportation Research Board, and other information retrieval systems. Key project investigators have been involved in the study of California's HOV lanes since their inception and already had extensive libraries of relevant reports and data. In addition, state and national experts having HOV experience were contacted for additional input. Particular attention was given to seeking input from CALTRANS headquarters and district staff members and the Transportation Research Board's Standing Committee on HOV Systems. The objective of this task was to synthesize current knowledge of the effectiveness of HOV lanes in terms of vehicular flow, person flow, vehicle occupancy distributions, freeway congestion, and air quality considering the HOV lane(s) and adjacent mixed-flow lanes. The end product is a document synthesizing current knowledge and experience of the effectiveness of HOV lanes and methods for predicting air quality.

Task 2: Assemble and Analyze Historical and Current Field Data of HOV Facilities

A major task of this study was to assemble and analyze historical and current field data of selected HOV facilities with particular focus on existing California HOV facilities. Available historical field data was assembled for those mainline HOV lanes currently operating in California, as well as those, such as the Santa Monica Freeway Diamond Lanes and Alameda 580, which were once operational but are now defunct. Wherever possible, year-by-year data was assembled, with special attention paid to data points before and after HOV lane installation and before and after the introduction of significant system improvements such as freeway-to-freeway connectors or adjoining HOV lanes.

In addition to historical information, available data on current performance was obtained for each mainline HOV lane currently operating in the state. Data included vehicle volumes and occupancy counts in the HOV lanes and adjacent mixed-flow lanes (from CALTRANS reports); and speed and delay data comparing HOV lanes with mainline performance (from PeMS data).

The data analyzed included year-to-year vehicular throughput and occupancy in the HOV lanes, mixed-flow lanes, and for the total freeway. Project team members worked with the various

CALTRANS district offices and headquarters to identify, select, assemble, and collect selected field data for representative locations.

Task 3: Assessment and Development of Methodologies for Estimating Air Quality

Two methodologies were developed for estimating air quality consequences of HOV lanes on freeways. One methodology was based on the use of the FREQ simulation model that currently includes the estimation of air quality. The other methodology was based on the use of the PeMS database that provides on-line traffic performance information at many locations in California but does not currently include the estimation of air quality.

The current version of the FREQ model includes the prediction of air quality as well as traffic performance. The air quality predictions include HC, CO, and NO_x as a function of predicted traffic intensity and performance, vehicle fleet year, and vehicle classification. The air quality predictions are made for each section of the freeway and for each time interval based on traffic performance predictions and aggregated for the entire freeway study section over the study duration. The previously incorporated air quality prediction subroutines were based on earlier California Air Resources models. This methodology was assessed in light of knowledge gained from the literature review, interviews, and synthesis of current knowledge (Task 1). The previous methodology within the FREQ model was modified and tested to represent the most up-to-date and comprehensive methodology for predicting air quality.

The current PeMS database provides on-line traffic performance information such as flows, percent occupancies, densities, and speeds for many freeway stations in California. However it does not include air quality predictions. Based on the literature review and synthesis of current knowledge (Task 1) and the modified air quality predictions in the FREQ model discussed in the previous paragraph, an off-line methodology was developed and tested to estimate air quality as part of the PeMS database. During future research, this off-line methodology could be implementation on-line as part of the PeMS database.

Task 4: Application of Modified FREQ Model to Evaluate HOV Lanes

The modified FREQ model was applied to two freeway study sections for the purposes of demonstrating and providing an assessment of the effectiveness of HOV lanes and their impact on air quality. One site represents typical northern California practice (peak-period only, unlimited access operations, and associated cut-off levels) while the other site represents typical southern California practice (24/7, limited access operating policies, and associated cut-off levels). The assessment includes vehicular and person travel in the HOV lane and adjacent mixed-flow lanes as well as air quality and fuel consumption consequences.

Sensitivity analysis were undertaken to assess the consequences on vehicular/person travel and air quality. The HOV lane sensitivity parameters included such elements as HOV lane location, vehicle occupancy distribution, priority cut-off level or occupancy requirement, design, access/egress limitations, growth consequences, and traffic intensity level.

Task 5: Application of Off-Line Modified PeMS Database to Evaluate HOV Lanes

The modified off-line methodology for estimating air quality based on the PeMS database was applied to one of the demonstration sites used in Task 4. One issue addressed in developing a methodology for using PeMS data to estimate air quality was an appropriate sampling rate. Some applications of the PeMS data base (notably the RTMIS data base developed by SCAG) aggregate data on a one-hour basis. Obviously, an average speed of 40 mph over one hour will have different air quality consequences depending on whether it was a consistent 40 mph or 30 minutes at 60 mph and 30 minutes at 20 mph. The research team explored this issue empirically by taking speed data at different intervals and monitoring the impact on air quality computations.

Task 6: Documentation and Presentation of the Effectiveness of HOV Lanes

The final task of the research was to develop a document that summarizes the effectiveness of HOV lanes in terms of vehicular and person travel in the HOV lane(s) and adjacent lanes, and the consequences to air quality. The methodologies developed are applicable to most existing HOV lane implementations as well as to many other HOV lane implementations expected to be considered in the near future. This document is based on the literature search and synthesis, the analysis of field data, developed air quality modeling, the modified FREQ model demonstration applications, and the off-line modified PeMS demonstration applications. The results of this research will be presented in a workshop forum.

1.3 ORGANIZATION OF REPORT

This document represents the Final Report on this project. It is divided into Seven Chapters plus a list of references and four appendices.

Chapter One is this introduction. Chapter Two describes the literature review and syntheses of current knowledge (Task 1). Chapter Three presents the work undertaken to assemble and analyze historical and current field data of HOV facilities (Task 2).

Chapter Four documents the procedures for developing methodologies for estimation air quality, both for the freeway simulation model FREQ, and for the PeMS off-line module (Task 3). Chapter Five contains a detailed description and results obtained in the application of the modified FREQ model to evaluate HOV lanes for two demonstration sites (Task 4). Chapter Six describes the application of the off-line methodology for estimating air quality based on the PeMS data base (Task 5). Chapter Seven contains a summary of the project. The report also contains a list of references and four appendices.

CHAPTER TWO

COMPREHENSIVE LITERATURE REVIEW AND SYNTHESIS OF CURRENT KNOWLEDGE

2.1 BACKGROUND

The HOV project's proposal describes this task and concludes with the following paragraph:

> *"Four months after the start of the research, the study team will produce an extensive reference list, along with summaries synthesizing the state of knowledge regarding the effectiveness of HOV lanes and their impact on air quality. This list will be a 'living document', updated throughtout the life of the project."*

In early January 2005 a progress report was distributed to Caltrans providing highlights of the initial HOV-related literature search (January 8, 2005, file "hovx20). The umbrella term for this initial search was 'HOV' and a total of 922 citations were identified. This set of 922 citations was broken down into sub-groups using additional key words. Key references for each sub-group were briefly described and the sub-groups included the following:

- California (128 citations)
- Inventories (7 citations)
- Manuals (35 citations)
- Bibliographies (36 citations)
- Caltrans (50 citations)
- Guidelines (54 citations)
- Air Quality (112 citations)
- Safety (168 citations)
- Effectiveness/Evaluation (337 citations)
- 2004 (21 citations)

2.2 OVERVIEW OF ACTIVITIES

The efforts on this task have gone in several directions in order to make the initial search more comprehensive and useful for Caltrans while at the same time to identify and prepare a synthesis of the most significant documents. These efforts have included further literature searches, obtaining guidance from a number of individuals including representatives of the project team, Caltrans, TRB's HOV Systems Committee, and other selected individuals. The team has also been participating in two current nationally pooled-funded HOV projects in which Caltrans is one of the sponsors. Finally, attention has been given to HOV-related web sites.

The products of these effort includes: 1) separate delivery of five copies of a CD containing abstracts of the citations for each of the previous mentioned sub-groups and (2) this synthesis of the most significant documents and other sources.

The following synthesis is divided into two major sections. In the first section, a one-page description of the eleven references that appear to be most significant are provided with title, source, date, authors, availability, abstract, and content. The second section provides reference citations of other selected recent documents divided into three groups: California, Other States, and Other.

2.3 SIGNIFICANT REFERENCES

The one-page description of the eleven references that appear to be the most significant are listed in this section.

HOV SYSTEMS MANUAL

Source: Transportation Research Board (NCHRP Report 414)

Date: 1998

Authors Texas Transportation Institute, Parsons-Brinckerhoff, and Pacific Rim Resources

Availability: ITS Library (.TA, 1001.5, .N3, no. 315)

Abstract: This report is a comprehensive and detailed HOV systems Manual that incorporates current guidelines and practices. The contents of this Manual are, therefore, of immediate interest to both highway and transit professionals in planning, designing, implementing, operating, marketing, and enforcing HOV systems. The Manual is also useful to those charged with achieving air-quality and congestion-management goals as well as policy makers.

Contents

Chapter 1	Guide to the HOV Systems Manual
Chapter 2	Introduction to HOV Facilities
Chapter 3	Policy Considerations with HOV Facilities
Chapter 4	Planning HOV Facilities
Chapter 5	Operation and Enforcement of HOV Facilities on Freeways and in Separate Rights-of-Way
Chapter 6	Design of HOV Facilities on Freeways and in Separate Rights-of-Way
Chapter 7	Operation and Enforcement of Arterial Street HOV Facilities
Chapter 8	Design of Arterial Street HOV Facilities
Chapter 9	Transit and Support Services and Facilities
Chapter 10	Supporting Programs and Policies
Chapter 11	Implementing HOV Facilities
Chapter 12	Public Involvement and Marketing Programs
Chapter 13	Monitoring and Evaluating HOV Facilities

GUIDE FOR HIGH-OCCUPANCY VEHICLE FACITIES

Source: American Association of State Highway and Transportation Officials (GHOV-3)

Date: November 2004

Authors AASHTO Subcommittee on Design

Availability: ITS Library (HE336, .B8G84, 2004a)

Abstract: This guide is intended as just that – a guide. Where this guide does not provide specific geometric information, please refer to "A Policy on Geometric Design of Highways and Streets" for guidance. In some chapters, this guide provides desirable and minimum cross-sections and design criteria. Prior to implementing designs that are less than the minimums, an engineering review should be completed with respect to the safety and operational impacts of these geometric elements and their justification. For minimum designs, the designer should review Section 2.1, which describes the link between design, operations, and enforcement of HOV facilities to better understand the conditions under which the minimum designs might be appropriate and what operational treatments might be necessary. The Federal Highway Administration (FHWA), Federal Transit Administration (FTA), state Department of Transportation (DOT), transit agency, city, and others should agree on the most appropriate cross-section and other geometric design elements. A formal design exception request may need to be processed to document the decisions and their approvals.

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HOV LANE ELIGIBILITY REQUIREMENTS AND OPERATING HOURS HANDBOOK

Source: HOV Pooled Fund Study and Federal Highway Administration

Date: Draft Final Report (May 2006)

Authors Battelle Memorial Institute and Texas Transportation Institute

Availability: Battelle Memorial Institute and Texas Transportation Institute
Federal Highway Administration

Abstract: Welcome to the HOV Lane Eligibility Requirements and Operating Hours Handbook. This handbook provides a comprehensive guide to assessing the potential impacts of changes in eligibility requirements and operating hours on high-occupancy vehicle facilities. While the handbook focuses on assessing potential changes in the operation of existing HOV lanes, if may also be used in planning new HOV facilities. The handbook is intended to meet the needs of various audiences. The primary audience of the handbook is transportation professionals responsible for planning, designing, funding, operating, enforcing, and managing HOV facilities. The secondary audience includes agency management personnel, policy makers, and other individuals interested in the effective and efficient operation of HOV lanes.

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HOV LANE ENFORCEMENT HANDBOOK

Source:	HOV Pooled Fund Study and Federal Highway Administration
Date:	Final Draft March 2006
Authors	Texas Transportation Institute and Battelle Memorial Institute
Availability:	Texas Transportation Institute, Battelle Memorial Institute, and Federal Highway Administration

Abstract: The Handbook will be of use to agencies involved in the planning, development, and implementation of 1) HOV enforcement policies and programs, and 2) the planning, design, and operation of HOV facilities. The audience for the Handbook and the supporting products includes representatives from state departments of transportation (DOT), Metropolitan Planning Organizations (MPOs), transit agencies, enforcement agencies, and other agencies responsible for planning, designing, developing, operating, and enforcing HOV facilities. The targeted end users of the Handbook includes planners, engineers, managers, and other staff at these agencies. The supporting materials are targeted toward top-level agency staff and policy makers.

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A REGIONAL HIGH OCCUPANCY VEHICLE SYSTEM PERFORMANCE STUDY FOR ORANGE, SAN BERNARDINO, AND RIVERSIDE COUNTIES

Source: Southern California Association of Governments (SCAG).

Date: September 2004

Authors Systan Inc.

Availability: Systan

Abstract: The High Occupancy Vehicle system in California has recently been the subject of media attention and legislature scrutiny, most notably in a January 2000 report from the legislation analysts office, which posed the question "HOV Lanes in Calfornia Are They Achieving Their Goal?" To answer this question and to respond to the media and legislature attention and concerns expressed by policy makers, the Southern California Association of Governments (SCAG) has engaged Systan et al to undertake a regional high-occupancy vehicle system performance study designed to ensure that the HOV facilities of Orange, San Bernardino, and Riverside Counties obtain the best possible performance from existing and planned investments.

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Chapter 2	System Performance
Chapter 3	Market Research
Chapter 4	Traffic Forecasts
Chapter 5	Design/Operation Issues
Chapter 6	Recommendations

2002 HIGH OCCUPANCY VEHICLE LANE MASTER PLAN UPDATE

Source:	Metropolitan Transportation Commission, Caltrans District 4 and the California Highway Patrol Golden Gate Division
Date:	January 2003
Authors	DKS and Parsons Brinckerhoff
Availability:	DKS

Abstract: The 2002 HOV Lane Master Plan includes a thorough review of current HOV lane performance. An assessment of HOV lane forecasts (2025) from the latest modeling conducted for the 2001 Regional Transportation Plan (RTP), and more current forecasts (2010) developed specifically for this plan also were completed. This assessment has led to the development of recommendations for how the HOV lane system could be expanded beyond what is already included in the 2001 RTP. HOV lane improvements that support further development of MTC's Regional Express Bus Program also have been of particular interest as part of the plan update, and the study includes recommendations for expansion of the express bus operations in the region.

Contents

FHWA/TRB MANAGED AND PRICED LANES WORKSHOP

Source: Federal Highway Administration and Transportation Research Board

Date: November 18-19, 2003

Authors Federal Highway Administration and Transportation Research Board

Availability: Federal Highway Administration and Transportation Research Board

Abstract: Potential policy, program and research initiatives to advance the planning, implementation and operation of managed lanes were the focus of the Transportation Research Board (TRB) and Federal Highway Administration (FHWA) two-day workshop in Key Biscayne, Florida on November 18 and 19, 2003. The objectives of the workshop were (1) to identify and prioritize potential research and technology transfer activities to advance the implementation of managed and priced lanes; and (2) to identify opportunities to champion and advance managed and price lane research-related initiatives, particularly within TRB. The structure of the workshop allowed participants to spend the first day focused on the broader concept of managed lanes, while the focus of the second day was narrowed to address priced lanes. This workshop serves as a first step by FHWA and TRB to receive focused feedback on managed lane issues. Further efforts to obtain feedback in the future can be expected as additional planning and coordination takes place.

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A GUIDE FOR HOT LANE DEVELOPMENT

Source: Federal Highway Administration

Date: 2003

Authors Parsons Brinckerhoff and Texas Transportation Institute

Availability: Federal Highway Administration

Abstract: This guide is intended to be a comprehensive source of collective experience gained from the nation's current and implemented high occupancy toll (HOT) lane projects. The guide presents a wide range of information on HOT lanes and is intended to assist transportation professionals contemplating specific projects, as well as others who wish to become more informed on the topic. While most transportation officials are familiar with the HOT lane concept, relatively few have had first hand experience with actual HOT facilities. Therefore, the need to learn from current experience is particularly important.

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FREEWAYS, HIGH-OCCUPANCY VEHICLE SYSTEMS, AND TRAFFIC SIGNAL SYSTEMS

Source: Transportation Research Board, Record 1856

Date: 2003

Authors As indicated below

Availability: Transportation Research Board

Abstract: The 2003 series of the Transportation Research Record: Journal of the Transportation Research Board consists of approximating 650 papers selected from 2100 submissions after rigorous peer review. The peer review for each paper published in this volume was coordinated by the sponsoring committee acknowledged at the end of the text; members of the sponsoring committees for the papers in this volume are listed in page ii. Many of these papers were presented a the TRB 82nd Annual Meeting in January 2003, and draft versions were included in the Annual Meeting Compendium of Papers CD-ROM. This particular record, Record 1856, contains papers sponsored by the Freeway Operations, HOV Systems, and Traffic Signal Systems Committees. There were four papers listed below that dealt with HOV Systems.

Contents Katherine F. Turnbull et al, "Effects of Changing Occupancy Requirements for High-Occupancy Vehicle Lane: El Monte Busway Case Study".

Darren Henderson, "State of the Practice in High-Occupancy Vehicle System Performance Monitoring".

Myron Swisher et al, "Life-Cycle Graphical Representation of Managed High-Occupancy Vehicle Lane Evolution".

Beverly Kuhn et al, "State Legislative Issues for Managed Lanes in Texas".

HOV LANES IN CALIFORNIA:
ARE THEY ACHIEVING THEIR GOALS

Source: Legislative Analyst's Office

Date: January 7, 2000

Authors Rebecca Long (under supervisor of Dana Curry)

Availability: Legislative Analyst's Office

Abstract: High occupancy vehicle (HOV) lanes have been a central part of California's strategy for alleviating congestion. Today, HOV lanes cover 925 lane miles of the state highway system and plans are underway to double this system over the next 20 years. Given population projections for the state (expected to grow by over 30 percent by 2020) and the limited amount of capacity on the state highway system, the Legislature, the Department of Transportation (Caltrans), and regional transportation planning agencies (RTPAs) ought to take a closer look at the degree to which HOV lanes are achieving the goals of congestion relief and improved air quality. This report examines the performance of the state's HOV lanes. It provides options to modify their use in order to ensure that the existing HOV lane infrastructure is used most efficiently and any future investments in HOV lanes will further the goal of congestion relief and improved air quality.

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MANAGED LANES WEB SITE
TEXAS TRANSPORTATION INSTITUTE

Source: Texas A&M University and Texas Department of Transportation

Date: Continuously being updated

Authors Texas Transportation Institute

Availability: Web Site "http://managed-lanes.tamu.edu"

Abstract: Working in support of the research sponsors, TxDOT and the Federal Highway Administration, the Texas Transportation Institute (TTI), assisted by Texas Southern University, is investigating the complex and interrelated issues surrounding the safe and efficient operation of managed lanes and is developing a managed lanes manual to help TxDOT make informed planning, design, and operational decisions when considering these facilities for their jurisdiction. This multi-year project has a considerable number of tasks that focus on topics within the key thrust areas of planning, design, and operations of managed lanes facilities. One activity of this program was the development and now the continuous updating of the 'managed lane' web site. The web site is divided into six major parts.

Contents

Section 1	About this project
Section 2	News
Section 3	Our Products
Section 4	Meetings and Events
Section 5	E-mail List Information
Section 6	Related Work

2.4 OTHER SELECTED RECENT REFERENCES

2.4.1 California

1. Caltrans, *Ramp Meter Design Manual*, California Department of Transportation, Sacramento, California, January 2000.

2. Caltrans Division of Traffic Operations, *High-Occupancy Vehicle (HOV) Guidelines for Planning, Design, and Operations*, California Department of Transportation, Sacramento, California, August 2003.

3. Los Angeles County Metropolitan Transportation Authority, *HOV Performance Program Evaluation Report*, prepared by Parsons Brinckerhoff, November 2002.

4. J. Rodier-Caroline et al, *A Comparison of High Occupancy Vehicle, High Occupancy Toll, and Truck Only Lanes in the Sacramento Area, University of California at Davis, 1999.*

5. Yonnel Gardes et al, Bay Area Simulation and Ramp Metering Study, University of California PATH Program, 2003

6. J. Supernak et al, *San Diego's Interstate 15 Congestion Pricing Project: Traffic-Related Issues*, Transportation Research Board, Record 1812, 2002.

7. Parson Brinckerhoff, *Orange County High-Occupancy Vehicle (HOV) Operations Policy Study,* Parsons Brinckerhoff, August 2002.

8. K.F. Turnbull et al, *Effects of Changing Occupancy Requirements for High-Occupancy Vehicle Lane – El Monte Busway Case Study*, Transportation Research Board, Record 1856, 2003.

9. Edward Sullivan, *Continuation Study to Evaluate the Impacts of the SR 91 Value-Priced Express Lanes,* Cal Poly State University, December 2000.

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2.4.2 Other States

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32. N.L. O'Connell et al, *HOV Lanes on the Long Island Expressway: How are they doing?*, Texas Transportation Institute, 2001.

33. P. Murray et al, *Defining Special-Use Lanes: Case Studies and Guidelines,* Center for Transportation Research, University of Texas, 2000.

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36. AASHTO, *A Policy on Geometric Design of Highways and Streets*, American Association of State Highway Officials. Washington D.C., 2001.

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38. C. Fuhs and J. Obenberger, *Development of High-Occupancy Vehicle Facilities: Review of National Trends,* Transportation Research Board, Record 1781, pp 1-9, 2002.

39. Federal Highway Administration, *10th International Conference on High-Occupancy Vehicle Systems*, Compendium of Papers, Held in Dallas, Texas, 2001.

40. L.G. Neudorff et al, *Freeway Management and Operations Handbook,* Federal Highway Administration, 2003.

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43. Billheimer, John, J. B. Moore, and Heidi Stamm*, High Occupancy Vehicle (HOV) Lane Marketing Manual*, prepared for the Federal Highway Administration (DOT-T-95-04) by SYSTAN, Inc. Los Altos, CA, September 1994. (to be updated in FY 2007/08).

2.5 UPDATE OF LITERATURE REVIEW

The project team has reviewed contributions appearing in the literature since the initial literature search was conducted and has added the following references to the list of key contributions.

44. Cassidy, Michael J., Carlos F. Daganzo, Kitae Jang, and Koohong Chung*, Empirical Reassessment of Traffic Operations: Freeway Bottlenecks and the Case for HOV Lanes,* Institute of Transportation Studies, University of California, Berkeley, CA, Research Report No. UCB-ITS-RR-2006-6, December 2006.

45. Chung, Koohong, Ching-Yao Chan, Kitae jang, David R. Ragland, and Yong-Hee Kim, *HOV Lane Configurations and Collision Distribution on Freeway Lanes—An Investigation of Historical Collision Data in California*, paper presented at 86th Annual Meeting of the Transportation Research Board, Washington, D. C., January 2007.

46. Cothron, A. Scott, Stephen E. Ranft, Carol H. Walters, David W. Fenno, and Dominique Lord, *Crash Analysis of Selected High-Occupancy Vehicle Facilities in Texas: Methodology, Findings, and Recommendations*, Report No. FHWA/TX-04/0-4434-1, prepared by Texas Transportation Institute for FHWA, May 2004.

47. Ojah, Mark, and Ginger Goodin, *Examination of Selected Safety Considerations in the Development of HOV Facilities*, paper presented at 85th Annual Meeting of the Transportation Research Board, Washington, D. C., January 2006.

48. TRB, *Air Quality 2006*, Transportation Research Board, 2006.

49. Turnbull, Katherine, *HOV Performance Monitoring, Evaluating, and Reporting Handbook*, prepared by Texas Transportation Institute for FHWA, December, 2005.

50. Turnbull, Katherine, *HOV Lanes and Hybrid Vehicles*, presented at the 86th Annual Meeting of the Transportation Research Board, Washington, D. C., January 2007.

In addition, the team has identified eighty other HOV references appearing in the years between 2005 and 2007 and has added these references to the overall list of citations originally prepared in Task 1.

CHAPTER THREE

PERFORMANCE OF CALIFORNIA HOV LANES

3.1 OVERVIEW

Task Two of this investigation of the effectiveness of HOV lanes entailed an analysis of historical and current field data on California's HOV facilities. Available historical field data were assembled for those mainline HOV lanes currently operating in the state, as well as those, such as the Santa Monica Freeway Diamond Lanes, which were once operational but are now defunct. Wherever possible, year-by-year data were assembled, with special attention paid to data points before and after HOV lane installation and before and after the introduction of significant system improvements.

Figure 3.1 lists the number of directional miles of HOV lanes in each CALTRANS District as reported in the most recent District HOV reports available in December 2005. In all, nearly 1200 miles of HOV lanes exist throughout the state. Those districts not listed in the figure currently have no operating HOV lanes, although District Five in San Luis Obispo has plans on the drawing board for HOV lanes on Route 101 in Santa Barbara and Route 1 in Santa Cruz.

DISTRICT NO.	HOV LANE MILES
DISTRICT THREE	70.8
DISTRICT FOUR	318.5
DISTRICT SEVEN	422.6
DISTRICT EIGHT	91.2
DISTRICT ELEVEN	28.3
DISTRICT TWELVE	240.9
TOTAL	1172.3

Figure 3.1. HOV Lane Miles by District

Data availability varied widely from district to district. Districts 3, 4, and 7 had typically collected performance data conscientiously, while records of other districts showed significant gaps. Few districts collected the "Before" data needed to support detailed "Before/After studies of the impacts of HOV lanes. The following sections of this chapter organize findings for each District in terms of historical trends, current performance, and public opinion.

3.2 DISTRICT THREE

3.2.1 System Map

CALTRANS District Three comprises eleven counties in the Sacramento Valley and Northern Sierras. As of December, 2003, the area had 70.8 directional miles of HOV lanes in the Sacramento Metropolitan Area, including

- 28.6 miles (14.3 in each direction) on State Route 99 running from south of Elk Grove Boulevard to E Street on Route 51;
- 23.0 miles (11.5 in each direction) on US-50 between El Dorado Hills Boulevard and Sunrise Boulevard; and
- 19.2 miles (9.6 in each direction) on Interstate 80 between Riverside Boulevard and Longview Drive.

A map of existing HOV freeway routes in District Three appears in Figure 3.2.

3.2.2 HOV Freeway Inventory

Current Information Appendix D contains an inventory of HOV freeway lanes in District Three. The inventory, assembled from data in the most recent (December 2004) District Three HOV Report, lists routes and lane miles by direction, along with occupancy requirements, operating hours, opening dates, and dates and descriptions of subsequent modifications. All HOV lanes in District Three require two or more occupants for legal use of the lanes.

Data Availability. District Three has produced detailed annual reports on their HOV system for the years 1991 through 2004. These reports include data on traffic volumes, people movement, occupancy rates, violations, enforcement, accidents, and time savings. "Before" data documenting corridor operations prior to lane installation each of the three major area HOV lanes are also available in these references.

Figure 3.2 District Three High Occupancy Vehicle Lanes

3.2.3 Historical System Performance

The following charts document various aspects of the year-by-year performance of the HOV lanes on State Route 99 in District Three from their inception to 2003.

Growth of Volume. Figure 3.3 plots the growth of traffic volumes in the SR-99 HOV lanes from their introduction in November 1990 through 2003.

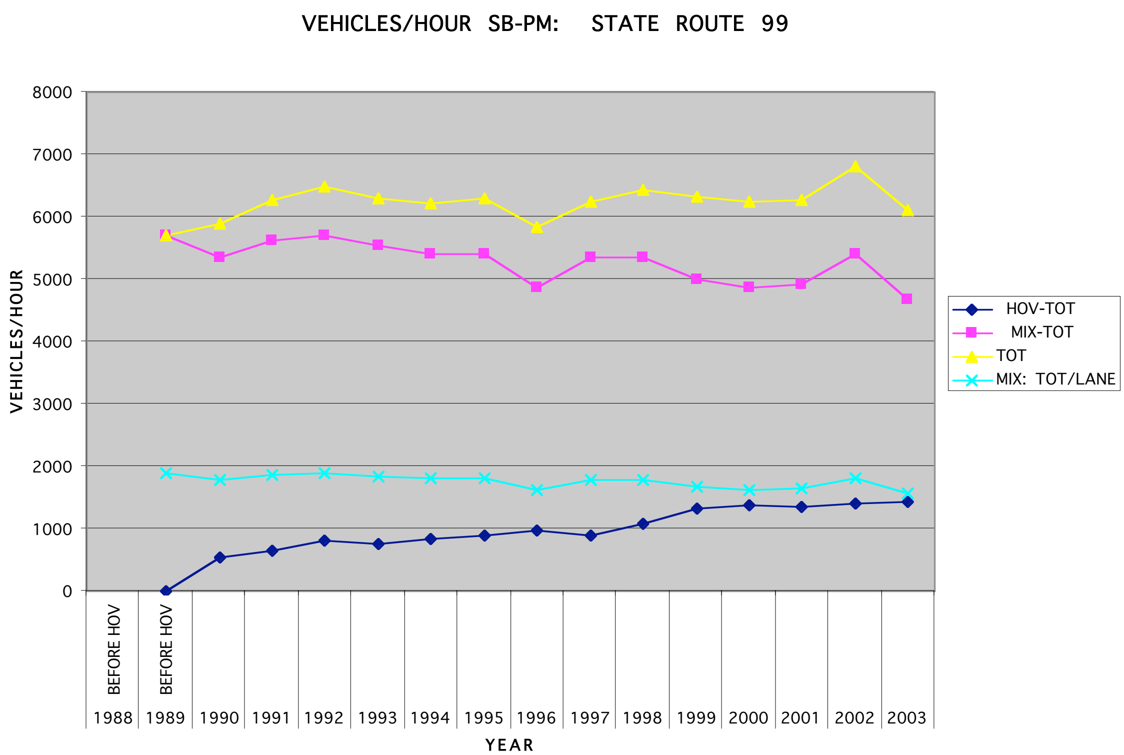


Figure 3.3 HOV Lane Traffic Over Time (Veh/Hr, SB PM)
State Route 99: Caltrans District Three

The figure shows a steady growth in the volume of traffic using the southbound HOV lane on SR 99 during the peak evening hour. During the first year of operation, only 550 vehicles were observed using the lane during the peak hour. By 2003, this volume had grown to 1420 vehicles per hour, just below the average of 1560 vehicles per hour observed in the three mixed flow lanes. While traffic in the HOV lanes was growing over time, traffic in the mixed flow lanes was dropping slightly. By 2003, therefore, when the number of vehicles in the average mixed flow lane had fallen to within 10% of the number in the HOV lane, the HOV lane was carrying 83% more people than the average mixed flow lane.

<u>Incidence of Ridesharing</u>. Figure 3.4 plots the growth in the incidence of ridesharing on State Route 99 from the introduction of the HOV lanes in November 1990 through 2003.

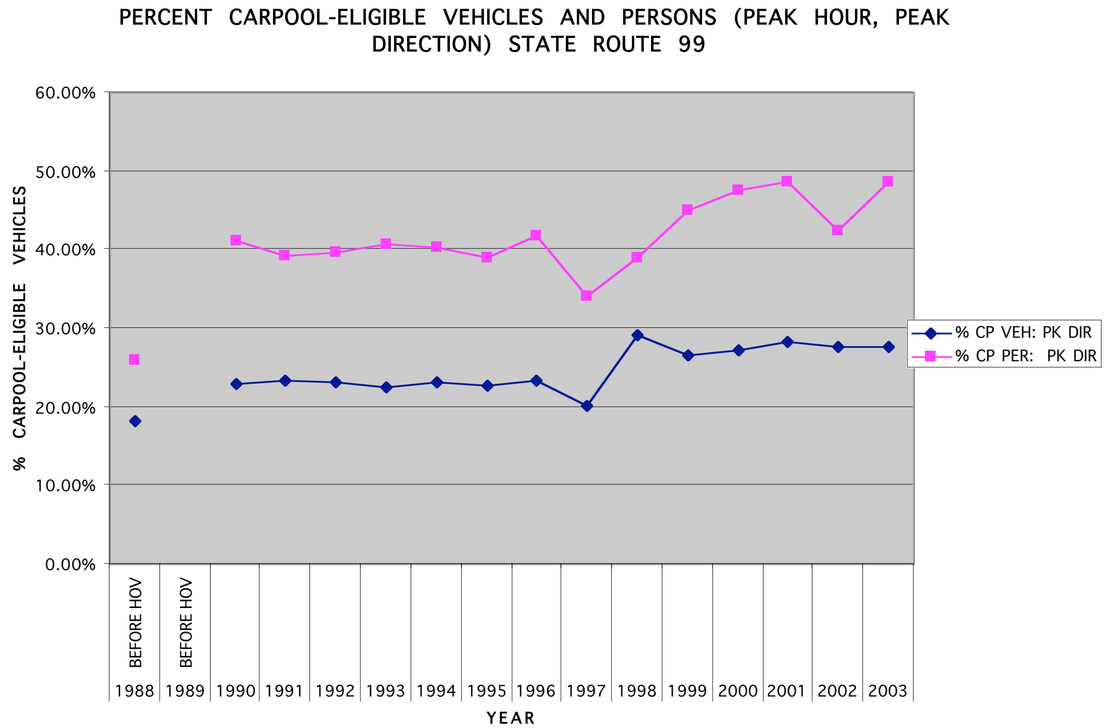


Figure 3.4 Percentage Of Carpool-Eligible Vehicles And Persons Using State Route 99 During The Peak Morning And Evening Hours

As would be expected, the increase in HOV lane traffic on State Route 99 has been accompanied by an increase in the incidence of ridesharing. When HOV lanes were introduced in November 1990, the percentage of vehicles carrying two or more persons during the peak hour jumped from 18.3% to 22.8%, while the number of people in these vehicles jumped from 26.0% of those using the freeway to 41.1%. The incidence of ridesharing vehicles and persons held fairly steady for seven years, and then rose again following the lengthening of the HOV lanes in 1997. By 2003, the incidence of vehicles carrying two or more persons had risen to 27.7%, just over one quarter of the peak-hour traffic, while the number of persons in these vehicles had risen to 48.7% of all those using the freeway.

Time Savings. Figure 3.5 shows the travel times in the southbound HOV lane and adjacent mixed flow lanes on State Route 99 from1990 through 2003. When the HOV lanes were first introduced, the time savings available over their 3.9 mile length were relatively small—amounting to less than one minute. As congestion increased in the mixed flow lanes, the available time savings jumped to 4 minutes in 1995, and rose again to 5.5 minutes in 1997, when the length of the HOV lanes was extended from 3.9 miles to 9.7 miles. By 2003, the recorded savings had risen to 6.67 minutes, or just under a half minute per mile over the 14.3 mile length of the lanes.

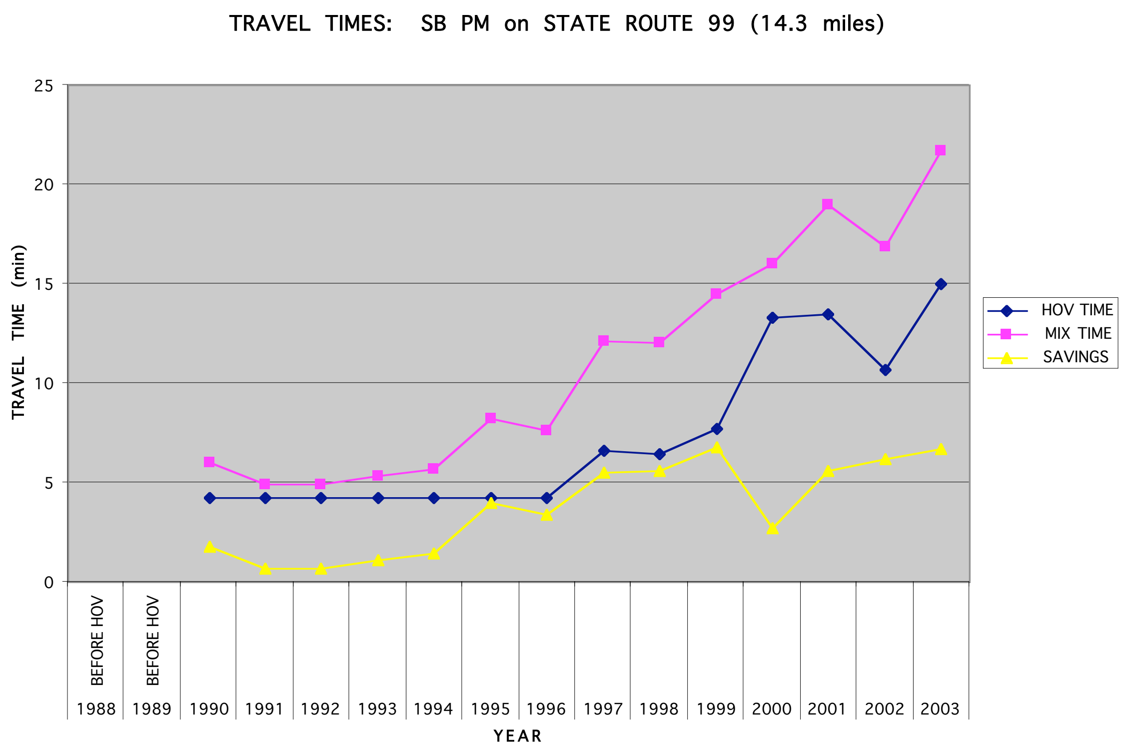


Figure 3.5 Travel Time Savings—SB PM On SR 99
Caltrans District Three

<u>Violation Rates</u>. Figure 3.6 tracks the violation rates observed during the peak hour of travel in the Northbound and Southbound HOV lanes on State Route 99.

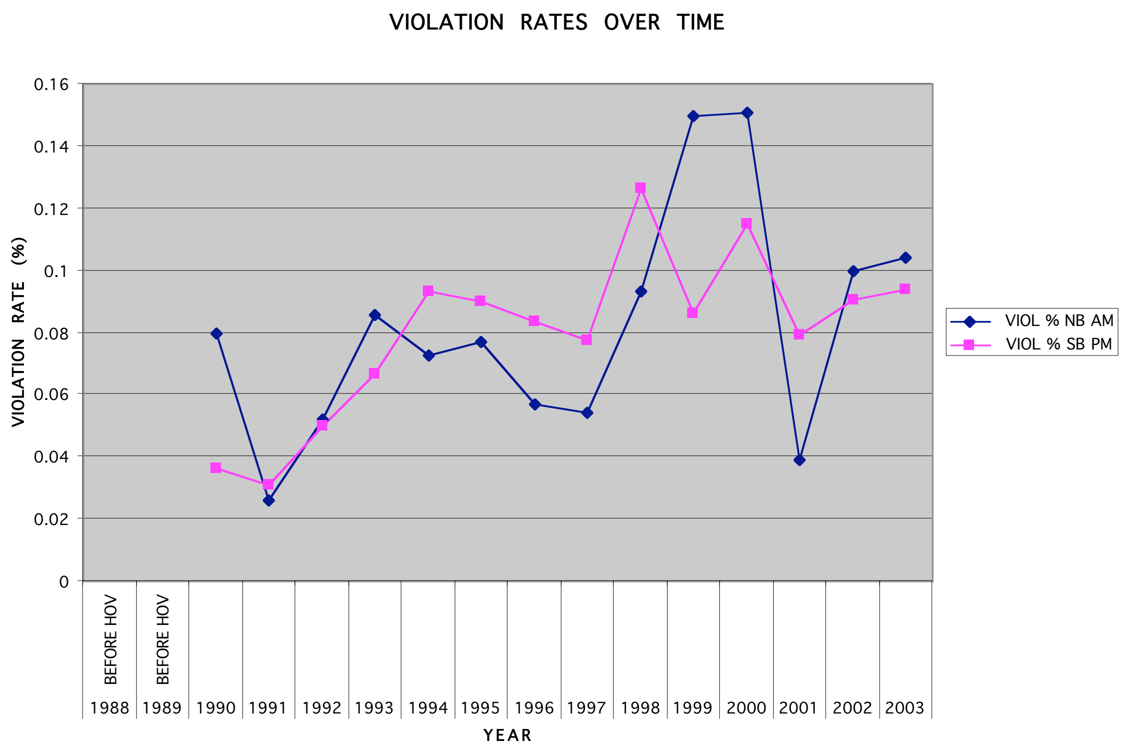


Figure 3.6 Violation Rates Over Time
State Route 99, Caltrans District Three

Violation rates on the State Route 99 HOV lanes have grown over time in both the northbound and southbound directions. In the southbound direction, violation rates during the peak evening hour currently hover around 10%, the level generally identified as the limit of acceptability. In the northbound direction, violation rates rose above this level (to 15%) in both 1999 and 2000, but counts during the morning peak in these years were affected by darkness. Past studies have shown that violation rates typically increase during pre-daylight periods, when it is hard to detect the number of occupants in a car visually and, consequently, violations are difficult to enforce.

3.2.4 Safety

Figure 3.7 tracks the accident rates recorded in the Northbound and Southbound directions over the stretches of State Route 99 augmented by HOV lanes. The depicted rates are measured in accidents per million vehicle miles over a 24-hour period, but the majority of recorded accidents reflect collisions occurring during the commute hours when HOV lanes were operating.

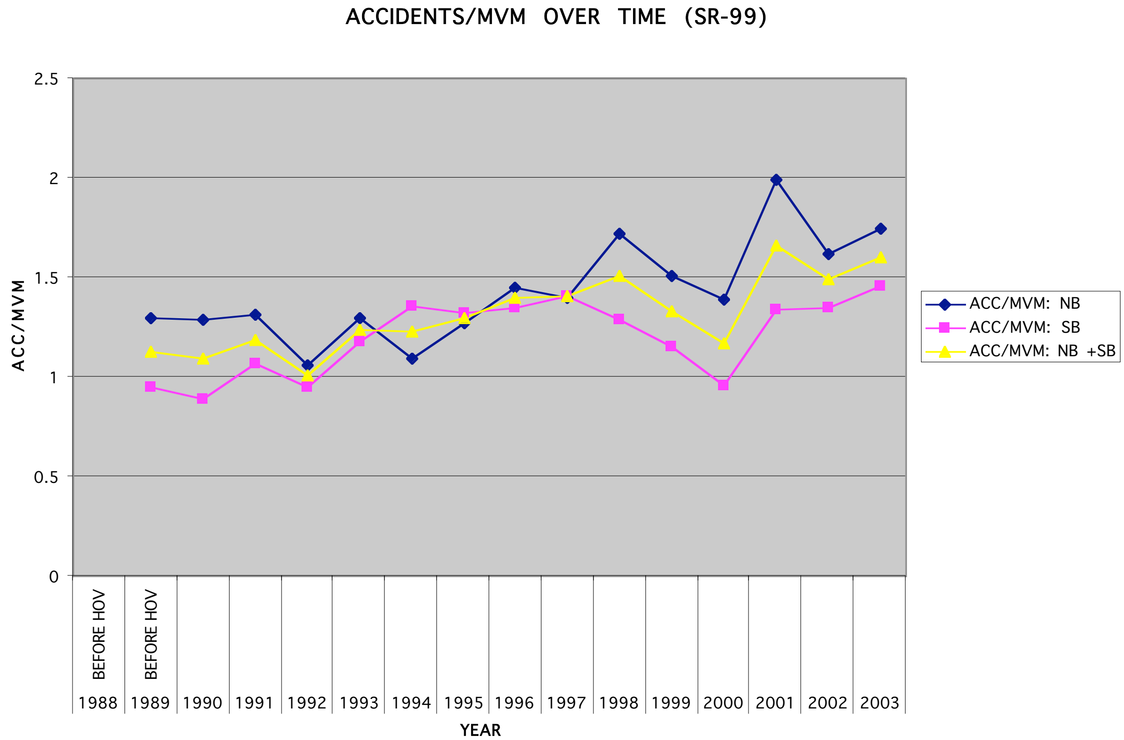


Figure 3.7 Accidents Per MVM On SR 99

The chart shows that accident rates remained relatively stable during the first three years following the introduction of HOV lanes on SR 99, and then followed an upward trend between 1995 and 2003. By 2003, the reported number of accidents per million vehicle miles in both directions had reached 1.6, an increase of 42% over the rate of 1.125 reported just before the HOV lanes were introduced. Accident rates were heaviest in the northbound direction, reportedly because the congestion in that direction is more pronounced during the morning peak.

The annual HOV reports produced by District Three note that the accident rates experienced on SR 99 are "…not unusual when compared with other freeway segments in Sacramento" (1999 report) and there is "…no indication that HOV lanes have caused an increase in actual accident rates" (1996 report).

The question of safety is one of the most vexing associated with HOV lane operations. On some projects, such as the Santa Monica Diamond Lanes and Route 237 in Santa Clara, California, accident rates have increased significantly following the introduction of HOV lanes. Yet other concurrent flow lanes have been installed with no increase in accidents. District Three's HOV lane reports suggest that the majority of collisions comprising the accident rate are congestion related and occur during commute hours. Another study of HOV lane safety has noted that "…the traffic congestion experienced on the freeway overwhelmed all other factors in determining safety. " Yet, by definition, the HOV lanes rely on congestion for the travel time savings needed to attract carpoolers. To the extent that the congestion accompanying the introduction of HOV lanes causes accidents, therefore, the lanes should be held accountable.

3.2.5 Current System Performance

The following charts offer lane-by-lane comparisons of such key performance measures as vehicle volumes, occupancies, travel time savings, and violation rates for the most recent year available, 2003.

Peak Hour Traffic Volumes. Recent vehicle volumes on District Three's HOV lanes are graphed in Figure 3.8, which shows peak-hour volumes in the peak direction of morning and evening flow.

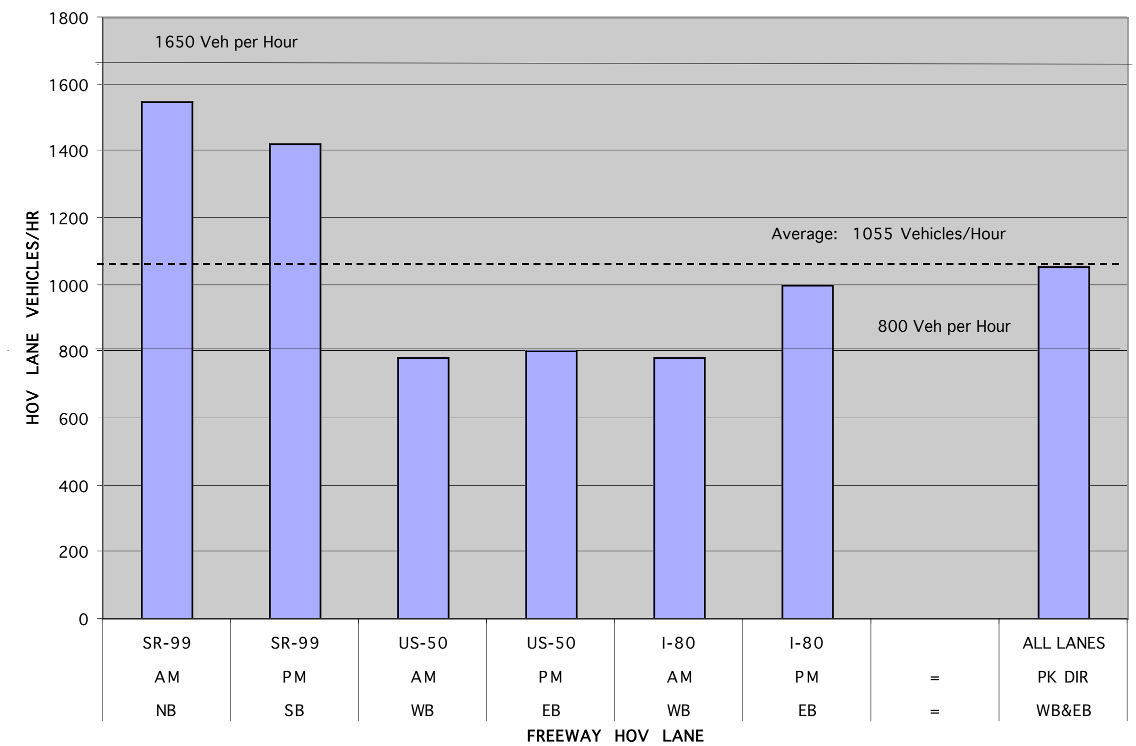


Figure 3.8 Peak Hour Vehicle Volumes, 2003/04
Caltrans District Three HOV Lanes

The horizontal lines of Figure 3.8 represent two generally recognized operating standards for HOV lanes.

(1) The lower level of 800 vehicles per hour, which is generally recognized as the minimum operating standard for a mature HOV lane (HOV Systems Manual, NCHRP Report 414). Operations below this level can experience the "empty lane syndrome" at which lanes appear underutilized.

(2) The upper level of 1650 vehicles per hour, at which point free-flow operations can begin to deteriorate, causing the time advantage offered by the HOV lanes to disappear. (Parsons Brinckerhoff, 2002)

As indicated in Figure 3.8, peak-hour vehicle volumes on all District Three HOV lanes either exceed or are just slightly lower than 800 vehicles per hour. This is true even of the most recently opened HOV lanes on I-80. In fact, the average peak-hour volume on all operating District Three lanes is 1055 vehicles per hour, so there is little danger that these lanes will fall victim to the "empty lane syndrome." In fact, the HOV lanes on SR-99 are currently approaching the upper limits of their capacity during the peak morning commute period.

<u>Person Volumes</u>. Figure 3.9 compares the percentage of freeway person trips carried by District Three HOV lanes and adjacent mixed-flow lanes in the primary direction of flow during the peak morning and evening commute hours.

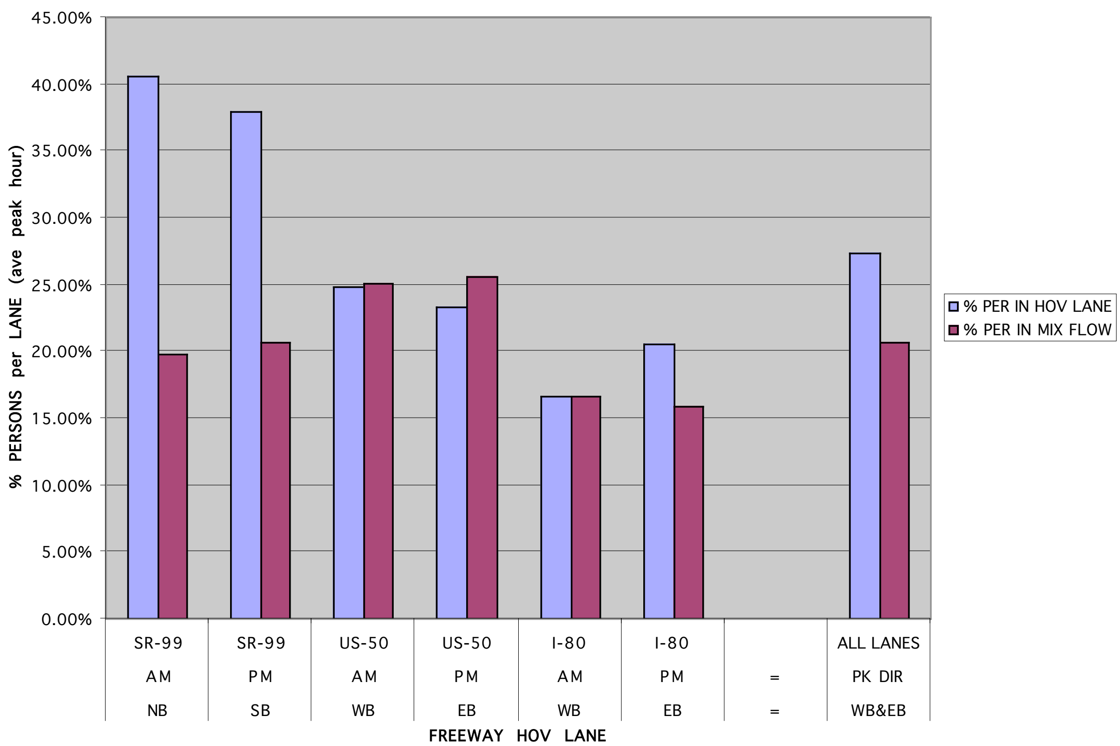


Figure 3.9 Percent Persons In HOV And Average Mixed-Flow Lanes (2003/04: Peak Hour, Peak Direction)

As would be expected, in nearly every case, the percentage of freeway travelers carried by the HOV lanes is significantly greater than the percentage carried by the average adjacent mixed-flow lane. The only exception is the recently formed HOV segment on eastbound US-50 during the evening peak. In all other cases, HOV lanes carry at least as many people as the average adjacent mixed-flow lanes in both peak directions. During the morning peak on northbound SR-99, moreover, the HOV lane carries more than double the number of people in the average mixed-flow lane. On the average, HOV lanes carry 27.3% of the people in District Three corridors, while the average adjacent mixed-flow lane carries only 20.6%. the predominant person-carrying capacity of the HOV lanes is achieved primarily through carpools, with relatively small contributions from buses.

Travel Time Savings. Figure 3.10 graphs the time savings available on each leg of District Three's HOV freeway network. Time savings were calculated by comparing the travel times of vehicles traveling the entire length of individual HOV lanes with the corresponding times recorded by vehicles in adjacent mixed-flow lanes.

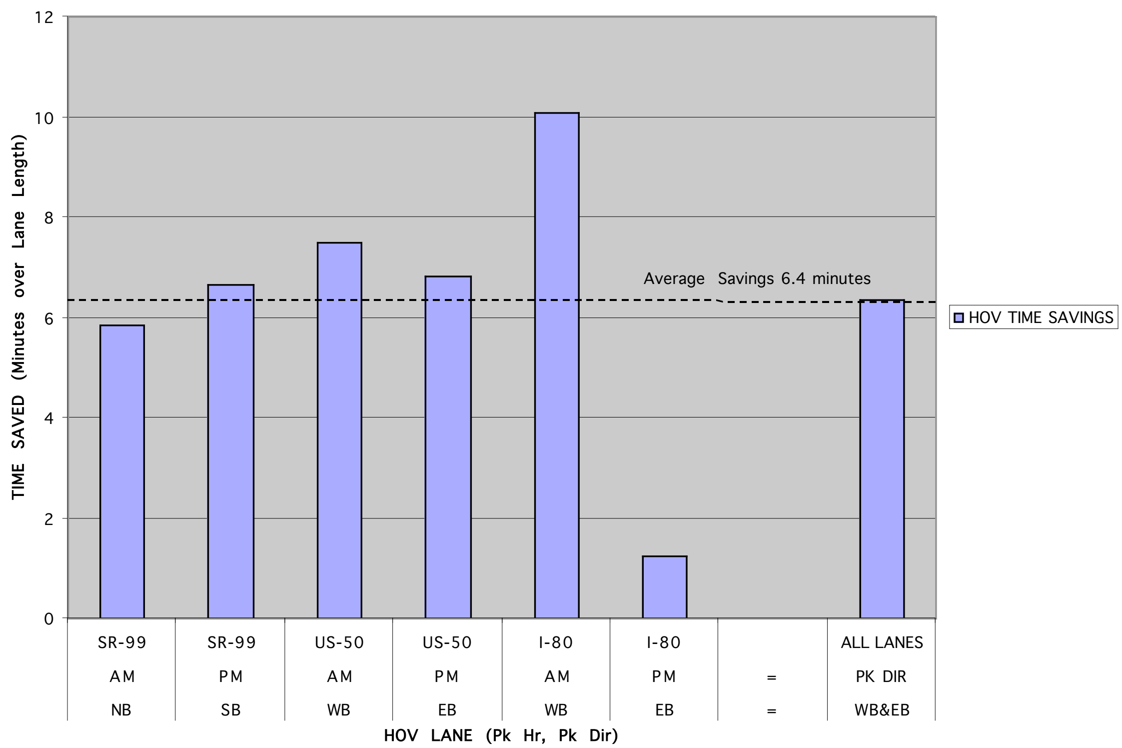


Figure 3.10 HOV Lane Time Savings (Peak Hour, Peak Direction)
Caltrans District Three HOV Lanes

The HOV Systems Manual (NCHRP Report 414) suggests that a savings goal of five minutes per trip, and/or one minute per lane mile, be used to gauge the success of HOV lane operations. As shown in Figure 3.10, the only HOV lane in District Three that does not meet the 5-minute criterion is the eastbound leg of I-80 during the evening peak. The HOV lane along this segment was opened in October 2003 by adding a lane to the five-lane freeway, and the added lane reduced congestion enough so that the HOV lane offered little time advantage. This situation can be expected to change over time as congestion increases. The average time savings for all District Three HOV lanes during the 2003/04 time frame was 6.4 minutes, or 0.54 minutes per HOV lane mile.

Violation Rates. Figure 3.11 plots the average violation rates recorded on District Three's HOV lanes for the year 2003 (2004 for I-80). In this case the violation rate is defined as the percentage of vehicles in the lane that fail to meet the minimum occupancy requirement.

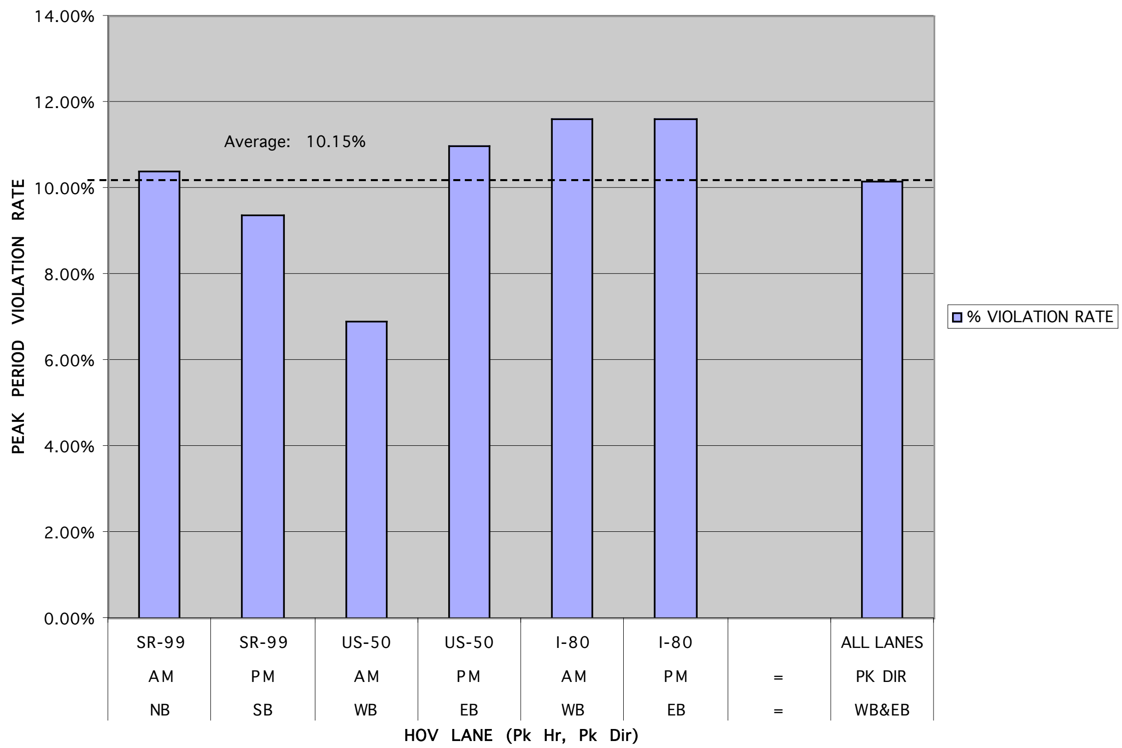


Figure 3.11 Violation Rates Per Lane
Caltrans District Three (2003/04)

The average violation rate was 10.15%, right at the 10% rate identified in past studies (for example, Billheimer, 1990) as a threshold for concern.

3.2.6 District Three Summary

The percentage of carpoolers in the freeway corridors served by each of District Three's HOV lanes has increased steadily, along with vehicle occupancy rates, following the introduction of the preferential lanes. The HOV lanes in service the longest, those on SR-99 are well utilized during peak commute periods and the most recently installed lanes, on US-50 and I-80, meet or exceed the minimum service criteria of 800 vehicles per hour established by the state.

For the most part, there is no way of knowing whether the measured increases in carpooling on District Three's mainline HOV lanes came from newly formed carpools or existing carpools which changed routes to take advantage of improved travel times. As time goes on, the question of whether the carpools added to the freeway mix following the introduction of HOV lanes were new or diverted becomes less and less important, since evidence from both Northern and Southern California surveys suggests that, over time, HOV lanes cause carpools to last longer, regardless of how those carpools came to be in the lanes in the first place.

3.3 DISTRICT FOUR

3.3.1 System Map

CALTRANS District Four comprises nine counties in the San Francisco Bay Area. As of December, 2003, the area had 318.5 directional miles of HOV lanes, including

- 279.3 directional miles of exclusive freeway lanes reserved for vehicles with two or more (2+) occupants;
- 31.4 directional miles of exclusive freeway lanes reserved for vehicles with three or more (3+) occupants;
- 7.8 directional miles of exclusive freeway lanes leading to four bridge toll plazas:
  - The San Francisco/Oakland Bay Bridge (ALA-80, 3+);
  - The Dumbarton Bridge (ALA-84, 2+);
  - The San Mateo Bridge (ALA-92, 2+); and
  - The Carquinez Straits Bridge (SOL-80, 3+);

This network of HOV lanes is supported by a variety of exclusive connectors and feeder lanes, including

- Four freeway-to-freeway connectors;
- Two HOV-only freeway on-ramps; and
- Sixty-six HOV bypass lanes at metered freeway on-ramps

A map of existing HOV freeway routes appears in Figure 3.12.

3.3.2 HOV Freeway Inventory

Current Information. Appendix D contains an inventory of HOV freeway lanes in District Four. The inventory, assembled from data in the most recent (December 2003) District Four HOV Report, lists routes and lane miles by direction, along with occupancy requirements, operating hours, opening dates, and dates and descriptions of subsequent modifications.

Data Availability. As of December, 2004, District Four had produced detailed annual reports on portions of the HOV system for the years 1987 through 2003. In general, ample data generally exists documenting HOV lane operations following implementation for these years. Unfortunately, records documenting corridor operations prior to lane installation are relatively rare. In preparing this report, “Before/After” data summaries were located only for the HOV lanes on SCL-101, SCL-237, and SCL-280.

Source: District Four HOV Report, December, 2003

Figure 3.12 Map Of District Four HOV Freeway Lanes

3.3.3 Historical System Performance

The following charts document various aspects of the year-by-year performance of the HOV lanes in CALTRANS District Four from their inception to 2003.

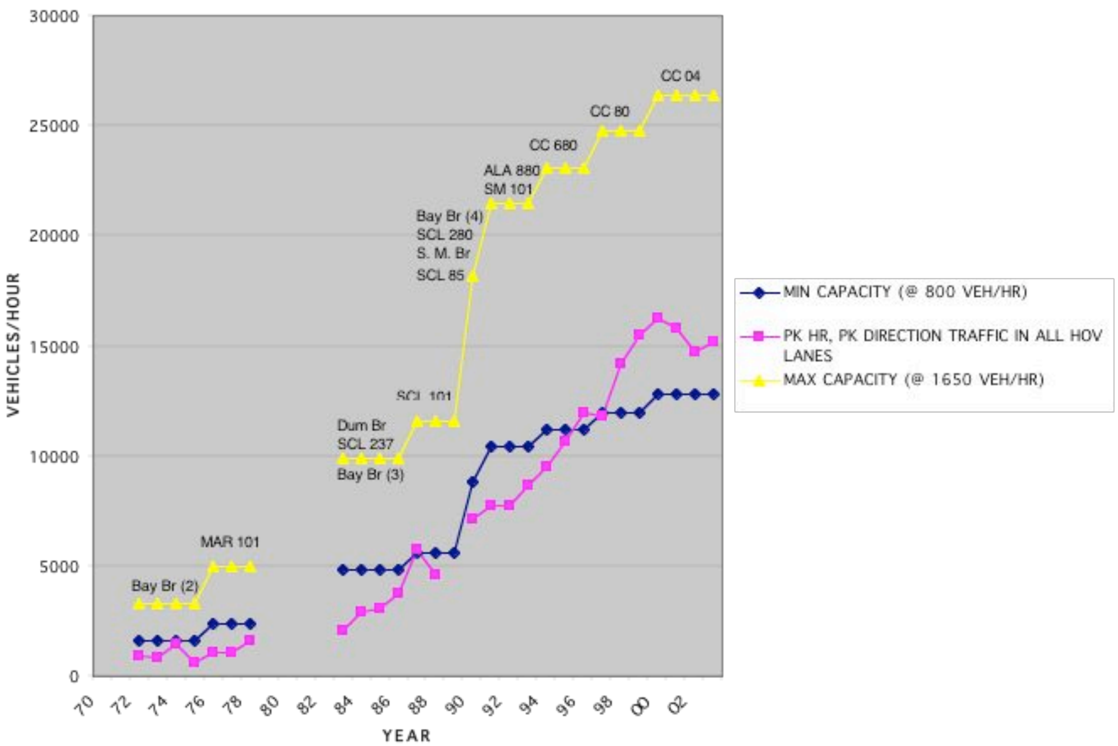


Figure 3.13 Vehicles/Hour On All Bay Area HOV Lanes

Growth of Volume and Capacity. Figure 3.13 plots peak hour, peak direction flow on all Bay Area HOV lanes as capacity has been added to the freeway network over time. The addition of lanes has been charted through two indices of capacity: A minimum capacity of 800 vehicles/hour, generally recognized as the minimum operating standard for a mature lane (HOV Systems Manual, NCHRP Report 414), and a maximum capacity of 1650 vehicles per hour, at which point free-flow operations begin to deteriorate. Beginning with two bus/carpool lanes on the westbound Bay Bridge approach, which opened in December, 1971, the number of HOV freeway lanes and the associated capacity has increased steadily, nearly doubling in 1990 and 1991 with the opening of a fourth HOV lane on the bay Bridge approach, the San Mateo Bridge bus/carpool lane, and HOV lanes on Santa Clara (SCL)-85, SCL-280, Alameda (ALA)-880, and San Mateo (SM)-101.

The total peak-hour, peak-direction traffic flow increased steadily as the number of HOV lanes increased, peaking at 16,260 vehicles per hour (an average of 1,017 vehicles per hour per lane) before dropping to 15,230 vehicles per hour in 2003. The average flow per lane exceeded the minimum threshold of 800 vehicles per hour in 1997 and currently averages 958 vehicles per hour on all Bay Area HOV lanes.

Although promising, the increase in vehicle flow depicted in Figure 3.13 need not reflect a shift in mode choice on the part of Bay Area drivers. It could be caused by a number of other factors, including population growth, route shifts by existing carpools, or the realization of latent demand as capacity is added to the freeway network. In order to explore the impact of the HOV lanes on carpool formation and mode choice, it is necessary to trace the incidence of carpooling on the affected freeways over time.

Incidence of Ridesharing. This section traces the percentage of carpool-eligible persons using Bay Area bridges and freeways following the introduction of HOV lanes. Carpool eligibility is defined with respect to the occupancy requirements of the individual lanes, and all eligible persons on the bridge or freeway are counted, whether or not they are observed using the HOV lanes.

Figure 3.14 charts the incidence of ridesharing over time on the HOV lanes at the toll plazas of three Bay Area bridges: The Bay Bridge, the San Mateo Bridge, and the Dumbarton Bridge.

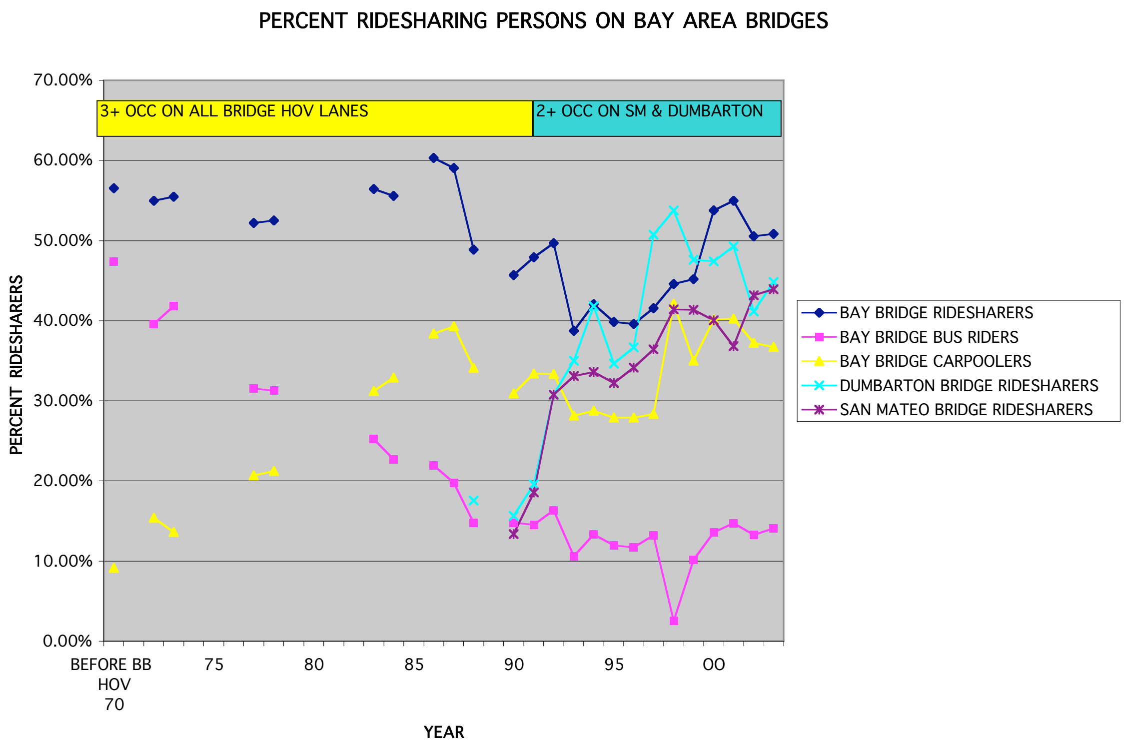


Figure 3.14 Percent Ridesharing Persons On Bay Area Bridges

Bay Bridge Ridesharing. The Bay Bridge HOV lanes were opened to 3+ carpools in December 1971. Since that time, the percentage of persons carpooling across the bridge during the morning peak has risen steadily from 9.1% of all commuters in 1970 to 36.7% of all commuters in 2003, with a slight drop following the 1989 earthquake, which shut down bridge operations for a month between October 17 and November 18. At the same time, since the introduction of BART in 1972, the incidence of bus riders has fallen precipitously, from 47.4% of all bridge commuters in 1970 to 14.1% in 2004. The BART-induced drop in bus riders has offset the growth in carpooling, so that the net percentage of ridesharers using the bridge HOV lanes has fallen from 56.5% to 50.8% since the introduction of the HOV lanes.

Dumbarton Bridge Ridesharing. HOV lanes on the Dumbarton Bridge were opened in October 1982. The percentage of legitimate carpoolers using the bridge HOV lanes rose to 30.8% following the reduction in occupancy requirements from 3+ to 2+ in January 1992 and has continued to rise, exceeding 50% of all commuters in 1997 and 2001 before dropping to 42.8% in 2003. This drop coincided with the completion of construction work on the San Mateo Bridge, which reduced delays at the toll plaza of the parallel bridge and undoubtedly drew some traffic away from the Dumbarton Bridge.

San Mateo Bridge Ridesharing. HOV lanes were introduced on the San Mateo Bridge in October 1989. As on the Dumbarton Bridge, the percentage of legitimate carpoolers rose to 30.8% of all commuters when restrictions were relaxed from 3+ to 2+ in January 1992, and has continued to rise, reaching 43.9% in 2003.

Thus the introduction of HOV lanes at the toll plazas of the three Bay Area bridges has led to a steady increase in the percentage of carpooling commuters crossing the bridges. Since the nature of the bridges effectively precludes the shifting of existing carpools from adjacent routes, it can be assumed that these increases represent either the formation of new carpools or an extension of the expected life of those carpools using the bridges.

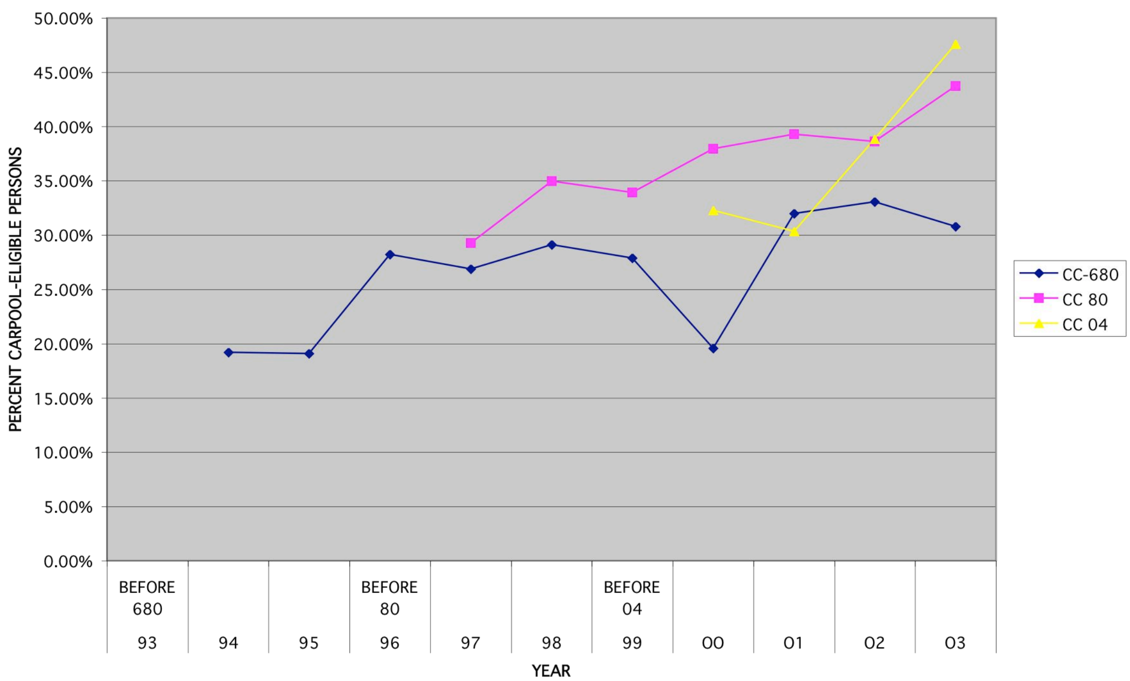


Figure 3.15 Percent Carpool-Eligible Persons On Contra Costa County Freeways

Ridesharing on Contra Costa County HOV Lanes. Figure 3.15 charts the incidence of carpooling over time on the HOV lanes on the following three Contra Costa County Freeways: CC-04, CC-80, and CC-680. Although no "Before" data are available to document the presence of carpoolers in the affected Contra Costa county corridors prior to the introduction of HOV lanes, the chart shows that the proportion of carpoolers on all tree freeways increased markedly following the introduction of HOV lanes. On CC-680, the percentage of carpoolers rose from 19.2% to 30.8% between the introduction of HOV lanes in 1994 and 2003. Carpool percentages on CC-80 increased from 29.3% in 1997, the first year of HOV lane operations, to 43.8% in 2003. Similarly, the proportion of carpoolers using CC-04 has increased from 32.3% to 47.6 % over the life of the HOV lanes.

Ridesharing on Santa Clara County HOV Lanes. Figure 3.16 charts the incidence of carpooling over time on the HOV lanes on the following four Santa Clara County Freeways: SCL-85, SCL-101, SCL-237, and SCL-280.

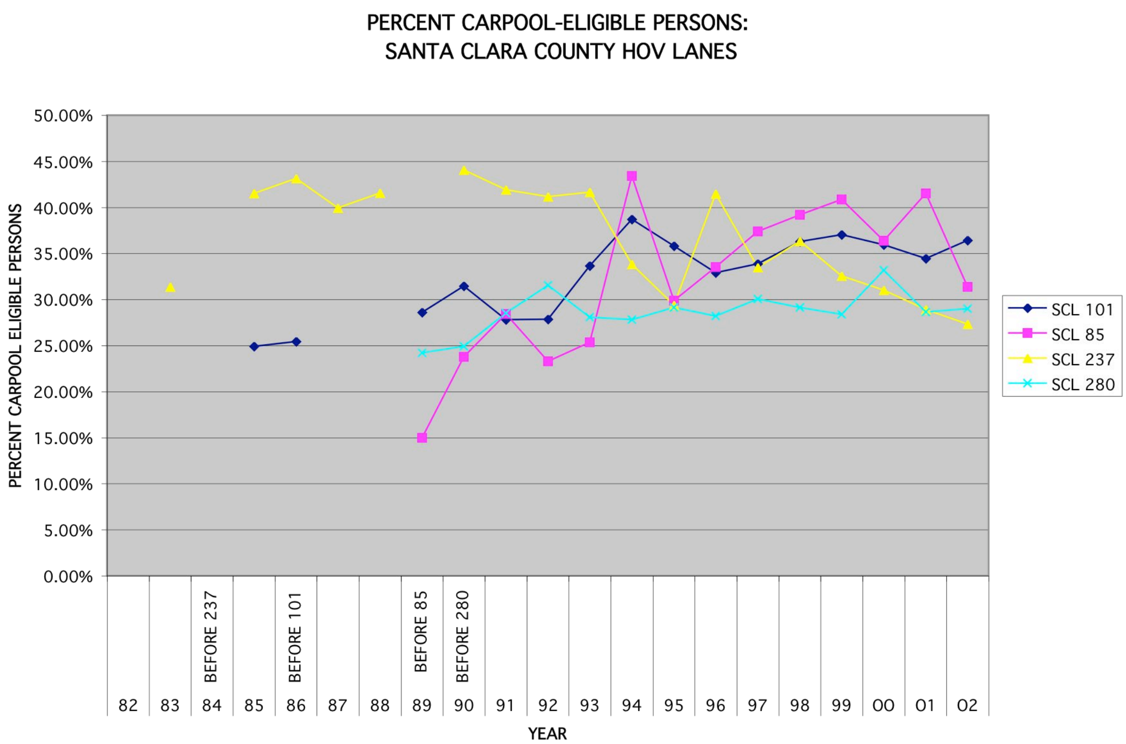


Figure 3.16 Ridesharing Over Time On Santa Clara County HOV Lanes

On all but one of the four Santa Clara County HOV lanes, the percentage of people eligible for the 2+ carpool lanes increased following the introduction of the lanes. On SCL-101, the percentage of carpoolers in the corridor increased from 24.9% prior to the opening of the first segment of HOV lanes in November 1986 to 36.4% in 2003. The proportion of carpoolers on SCL-85 rose from 15.0% when the lanes first opened in 1990 to 31.4% in 2003. While carpoolers represented just 24.2% of the morning commuters using the SCL-280 corridor prior to the opening of HOV lanes in December 1990, by 2003 this proportion had increased to 29.0%.

The SCL-237 corridor represents one of the only Bay Area corridors where the proportion of carpoolers has dropped following the introduction of HOV lanes. In 1984, before HOV lanes were installed on the SCL-237 expressway, 31.4% of the commuters in the corridor qualified as carpoolers.

This percentage had risen to 41.7% by 1994, but then began dropping when SCL-237 was upgraded to a freeway in 1995. By 2003, the percentage of carpoolers had dropped to 27.3%, below the 1984pre-HOV level. Two factors may account for this drop: When SCL-237 was upgraded to freeway status, the number of buses using the route dropped somewhat, and the corridor serves the heart of Silicon Valley, and therefore was affected by the drastic employment drop accompanying the business decline in 2000.

3.3.4 Current System Performance

The following charts offer lane-by-lane comparisons of such key performance measures as vehicle volumes, occupancies, travel time savings, and violation rates for the most recent year available, 2003.

<u>Peak-Hour Traffic Volumes</u>. Recent vehicle volumes on District Four's HOV lanes are graphed in Figure 3.17, which shows peak-hour volumes in the peak direction of morning and evening flow.

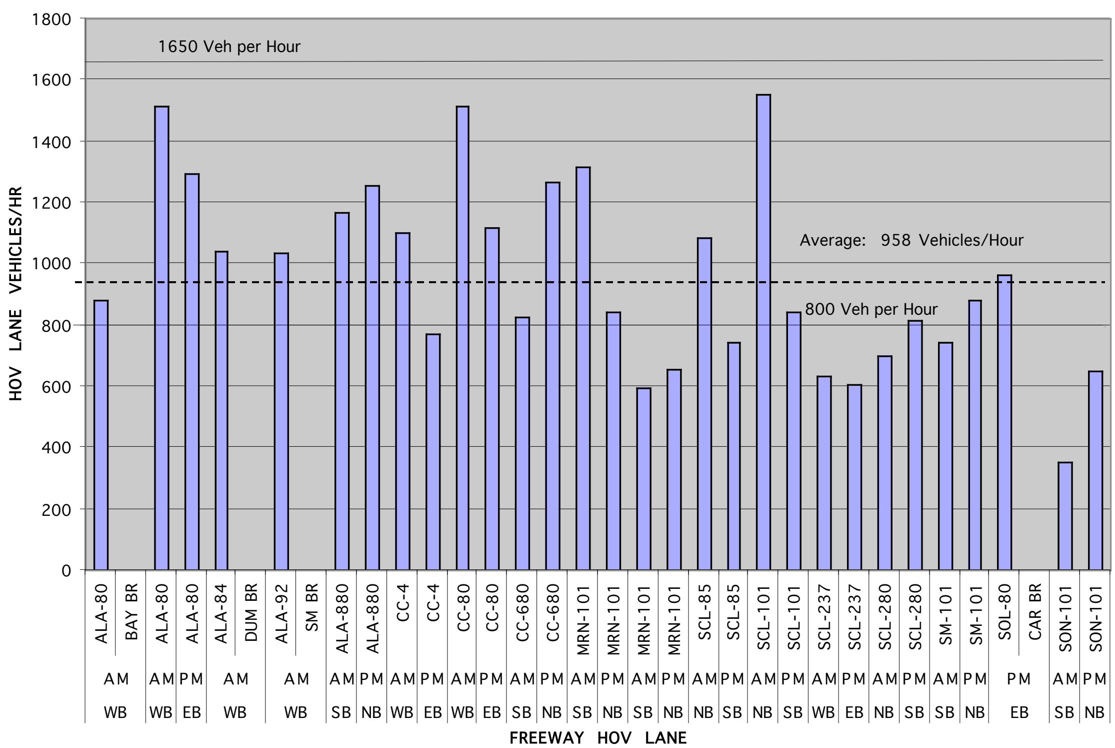


Figure 3.17 Peak Hour Vehicle Volumes, 2003
Caltrans District Four HOV Lanes

The horizontal lines of Figure 3.17 represent two generally recognized operating standards for HOV lanes.

(1) The lower level of 800 vehicles per hour, which is generally recognized as the minimum operating standard for a mature HOV lane. Operations below this level can experience the "empty lane syndrome" at which lanes appear underutilized.
(2) The upper level of 1650 vehicles per hour, at which point free-flow operations can begin to deteriorate, causing the time advantage offered by the HOV lanes to disappear.

As indicated in Figure 3.17, with the single exception of the recently opened lanes on Sonoma-101, peak-hour vehicle volume on all District Four HOV lanes exceed 600 vehicles per hour. In fact, except for SON-101, the southern portion of Marin-101, and SCL-237, all of the HOV lanes exceed the minimum threshold of 800 vehicles per hour. The average peak hour flow on all the lanes is 968 vehicles per hour, so that District Four HOV lanes are not likely to fall victim to the "empty lane syndrome." In fact, at least three lanes (ALA-80, CC-80, and SCL-101) approached the upper limits of their capacity during the peak morning commute period. District Four personnel report that all three of these lanes have experienced demands in excess of capacity and have occasionally broken down in recent years.

__Person Volumes.__ Figure 3.18 compares the percentage of corridor person trips carried by District Four HOV lanes and adjacent mixed-flow lanes in the peak direction of flow during the peak morning and evening commute hours.

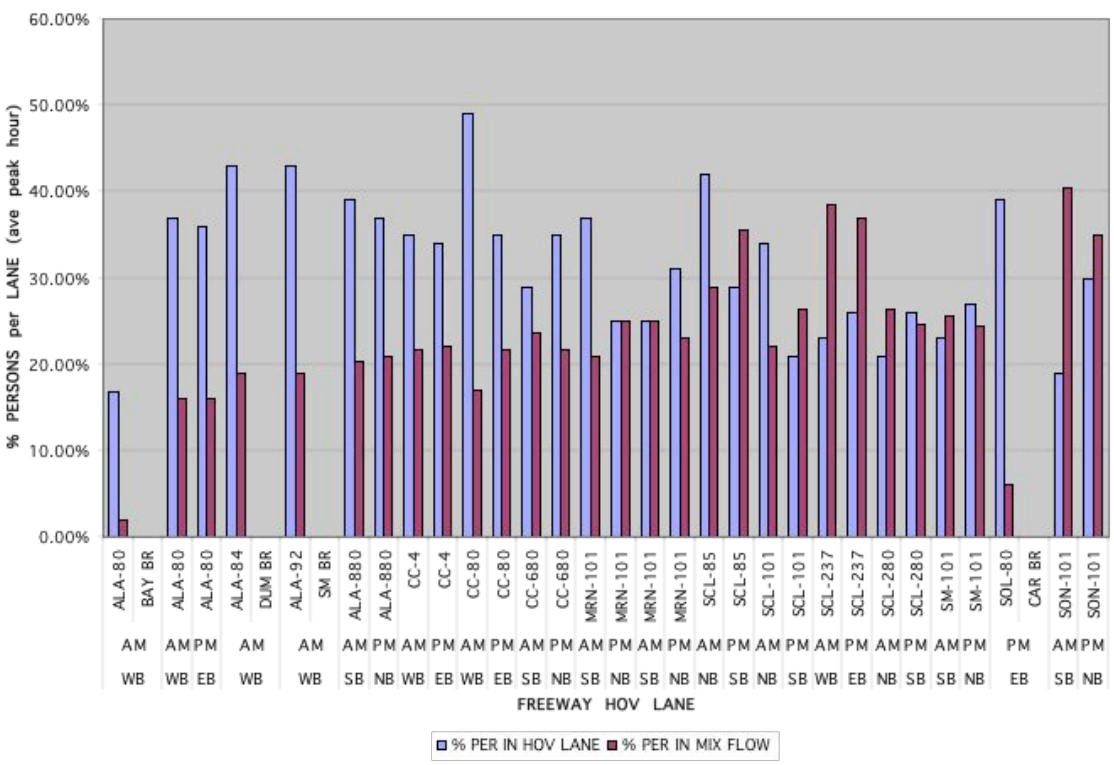


Figure 3.18 Percent Persons In HOV And Average Mixed-Flow Lanes (Caltrans District Four, 2003: Peak Hour, Peak Direction)

As would be expected, in nearly every case, the percentage of corridor travelers carried by the HOV lanes is significantly greater than the percentage carried by the average adjacent mixed-flow lane.

Exceptions are the recently formed HOV lanes on Sonoma-101 and the long-standing HOV lanes on SCL-237. In all other cases, HOV lanes carry more people than the average adjacent mixed-flow lanes in at least one (and usually both) peak directions. On the average, HOV lanes carry 32.2% of the people in District Four corridors, while the average adjacent mixed-flow lane carries only 23.9%. the predominant person-carrying capacity of the HOV lanes is achieved primarily through carpools, with relatively small contributions from buses.

Travel Time Savings. Figure 3.19 graphs the time savings available on each leg of District Four's HOV freeway network. Time savings were calculated by comparing the travel times of vehicles traveling the entire length of individual HOV lanes with the corresponding times recorded by vehicles in adjacent mixed-flow lanes.

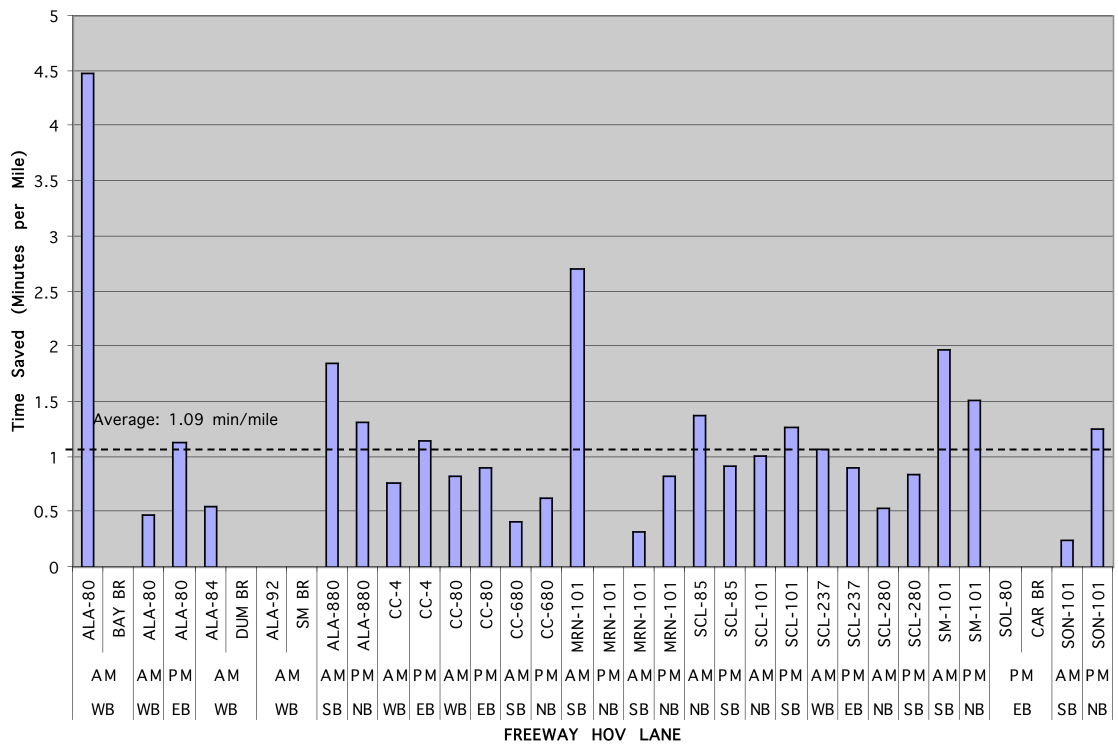


Figure 3.19 Time Savings Per HOV Lane Mile
Caltrans District Four, 2003

Travel time savings in Figure 3.19 are expressed in terms of minutes saved per mile of HOV lane. A somewhat arbitrary saving goal of one minute per lane-mile is sometimes used to gauge the success of HOV lane operations. As shown in Figure 3.20, every HOV lane in District four meets this criterion in at least one direction, and the average time savings for all the District Four HOV lanes recorded in 2003 was 1.09 minutes per mile, more than double the success threshold.

Violation Rates. Figure 3.20 plots the average violation rates recorded on District Four's HOV lanes for the year 2003.

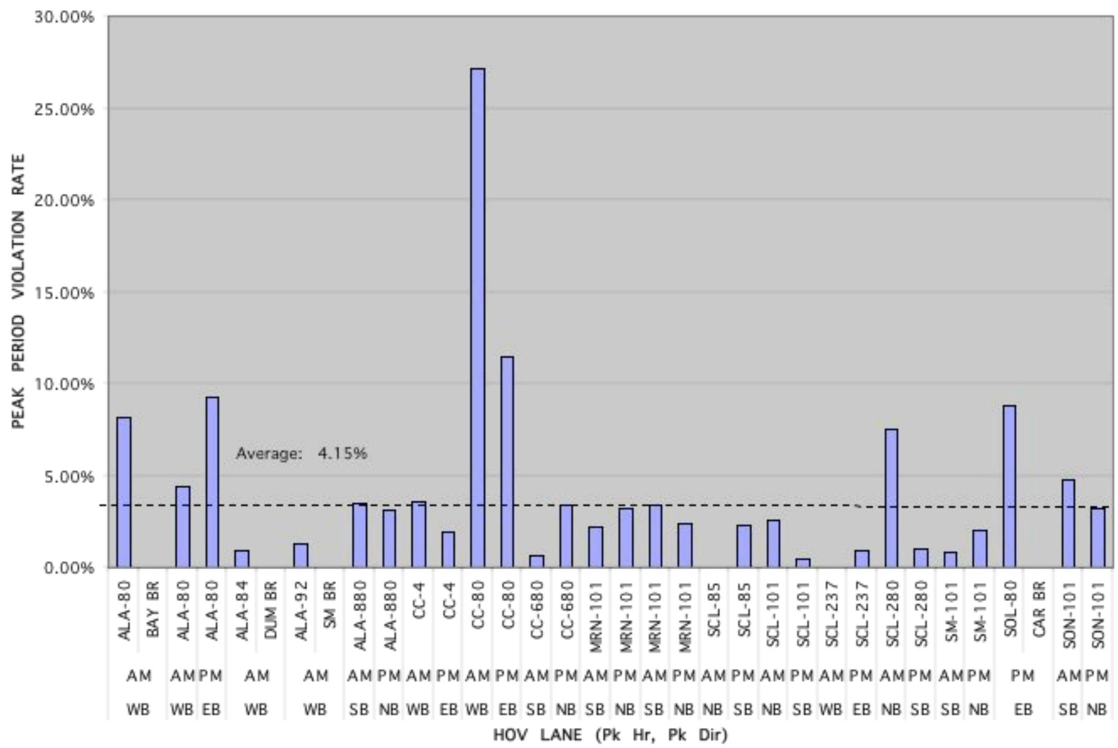


Figure 3.20 Violation Rates Per Lane
Caltrans District Four, 2003

The average violation rate was 4.15%, well below the 10% rate identified in past studies as a threshold for concern. Only one set of District four HOV lanes, the lanes on Contra Costa-90, exceed this threshold. The highest violation rates in the district were recorded on those lanes which, like CC-80, had 3+ occupancy requirements (ALA-80, the Bay Bridge, and SOL-80). While 3+ occupancy requirements raise the number of potential violators slightly, they also tend to raise violation rates more sharply, since there are fewer legitimate carpoolers in the lane to contribute to the denominator of the rate equation. In the case of District Four, the average violation rate on HOV lanes with 3+ occupancy restrictions is 9.5%. If District Four's 3+ lanes are ignored in computing an average violation rate, the District-wide violation rate for lanes with 2+ occupancy drops to 2.0%, less than half the overall average.

Congestion Patterns. A comparison of congestion patterns in CALTRANS District Four with those in Southern California, where HOV lanes operate 24 hours per day, seven days a week, shows that the peak operating hours in Southern California counties typically last longer than the peaks on District Four freeways. Figure 3.21 compares the peak flow patterns on four Northern and Southern California freeways with operating HOV lanes.

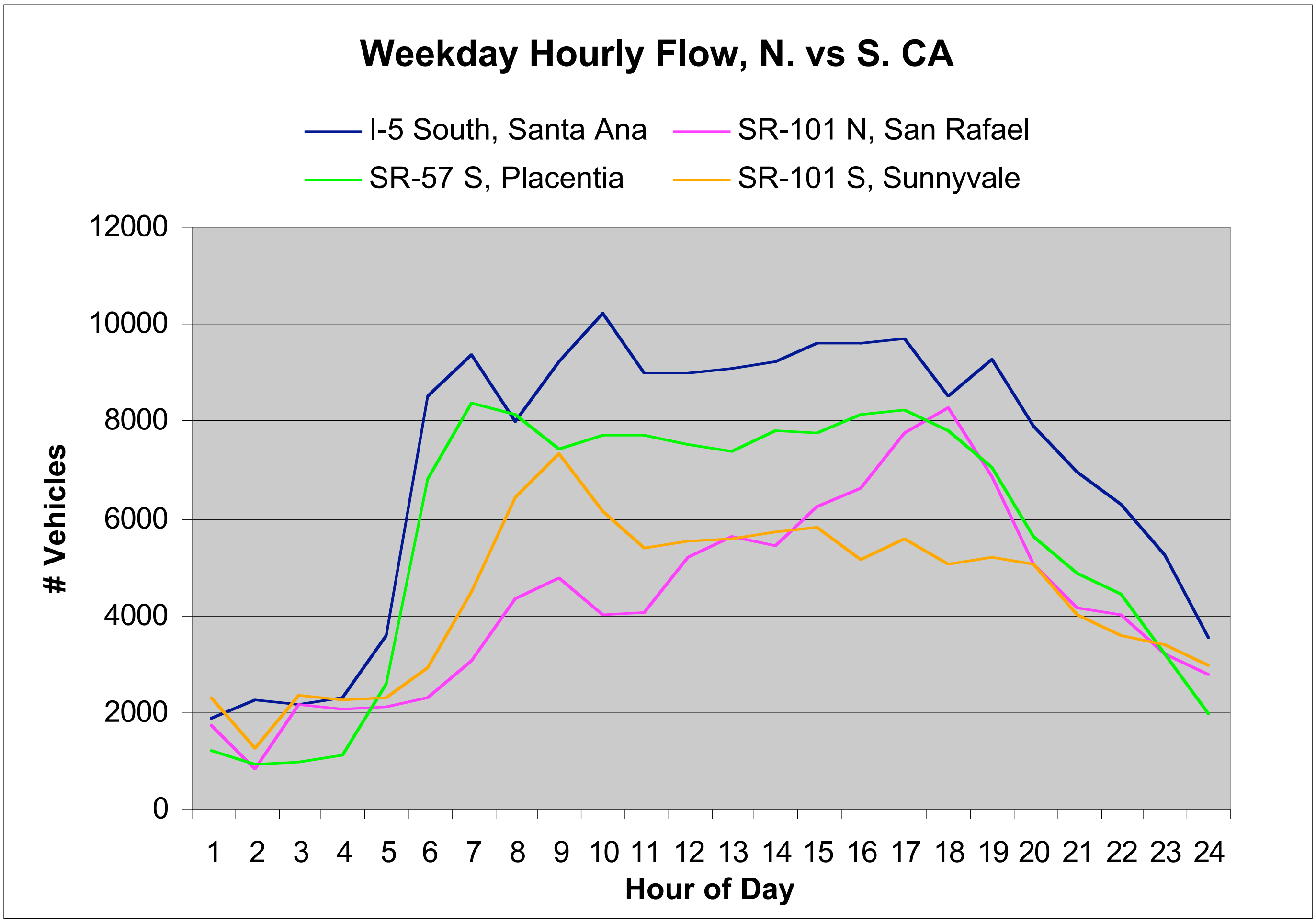


Figure 3.21 Comparison Of Congestion Rates In Northern And Southern California

Figure 3.21, taken from Freeway Performance Monitoring System (PeMS) data assembled in SYSTAN's evaluation of HOV lanes in Orange, San Bernardino, and Riverside Counties, shows that the two District Four freeways, Marin-101 in San Rafael and Santa Clara-101 in Sunnyvale experience pronounced peaks in the AM and PM, respectively, while the two Southern California freeways, I-5 in Santa Ana and SR-57 in Placentia show equally heavy volumes during both morning and evening peaks, and no let-up during the middle of the day. In every case, the Southern California freeways peak earlier and the peaks last longer than those observed on Northern California freeways.

The wide and spreading peak congestion periods during the weekdays in Southern California counties, compared with the pronounced peaks on District Four freeways, helps to explain the differing CALTRANS policies of 24/7 HOV operations in Southern California and peak-hour operations in Northern California.

3.3.5 Public Opinion

Introduction. Driver attitudes, perceptions, and opinions provide an important prism for viewing and evaluating high-occupancy vehicle lanes. In Southern California, public attitudes have undergone a remarkable change, from heated opposition to HOV lanes in the wake of the disastrous experiment on the Santa Monica Freeway to wide-ranging support of the current area-wide network. While public opinion in District Four never reached the low point set by the Santa Monica Diamond Lanes, certain early projects were viewed with a high degree of skepticism.

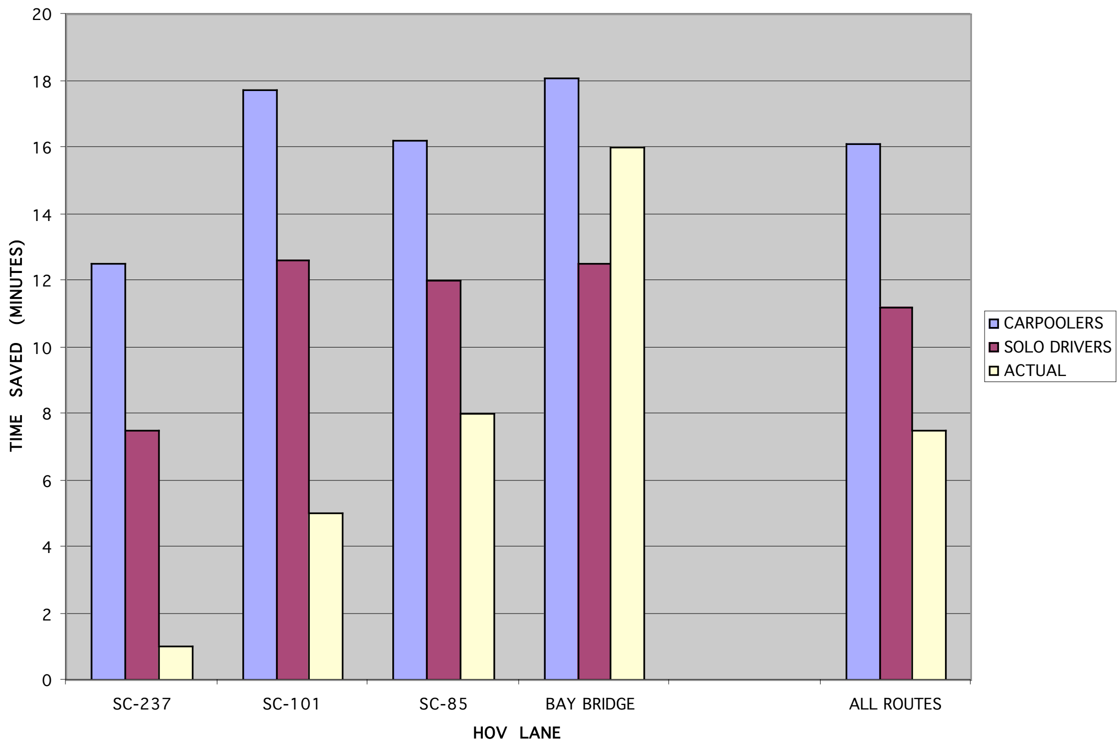
It is instructive to trace the attitudes of Bay Area drivers toward HOV lanes as revealed in focus groups and surveys conducted over the period of thirty years since preferential lanes were first introduced on the San Francisco/Oakland Bay Bridge. Driver surveys were conducted for a variety of purposes over this period, but the different surveys had enough in common to provide a glimpse of driver attitudes toward such issues as perceived time savings, carpool formation, violation rates, and general support for the HOV concept. Some of the key surveys of Bay Area drivers that have focused on HOV issues are listed below in chronological order.

YEAR	REPORT	SPONSOR	FIRM	SURVEY TYPE	TARGET
1981	TSM Project Violation Rates	CHP, CALTRANS	SYSTAN	Focus Groups, Mailback	CP+Solo
1990	HOV Lane Violation Rates	CALTRANS	SYSTAN	Focus Groups, Mailback	CP+Solo
1990	SF Bay Area HOV Lane User Study	MTC	SYSTAN	Telephone	CP
1995	O/D Studies in Eight Bay Area Corridors	CALTRANS	SYSTAN	Focus Groups, Mailback	CP+Solo
1997	O/D Studies on Three Bay Area Bridges	CALTRANS	SYSTAN	Focus Groups, Mailback	CP+Solo
1997	O/D Studies in Six Bay Area Corridors	CALTRANS	SYSTAN	Focus Groups, Mailback	CP+Solo
2002	2002 HOV Lane Master Plan Update	MTC, CALTRANS	DKS	Web Site, Mailback	CP+Solo

HOV Lane Support. Support for HOV lanes among Bay Area Drivers is currently positive. In a 2002 survey undertaken in support of the HOV Master Plan, DKS found that sixty percent of those drivers responding to a web survey supported the HOV concept. This represented 85% support from responding carpoolers and almost 50% support from non-carpoolers. Historically, support for the HOV concept has varied from project to project. In 1980, a SYSTAN survey for enforcement purposes found strong (70%) acceptance of the concept among drivers on Marin 101, but very weak support (31%) among drivers using Alameda 580, which featured unpopular HOV lanes that were underutilized, offered minimal time savings, and were ultimately opened to general traffic.

While the majority of non-carpoolers have historically supported carpool lanes, they tend to see them as half empty, while carpoolers see them as half full. The 2002 DKS survey found that 68% of responding carpoolers felt that the District Four HVO lane were well used, while 78% of non-carpoolers felt the same lanes were underutilized.

Perceived Time Savings. A common thread in all survey results, from the earliest to the most recent, is the agreement that HOV lanes save time for carpoolers and the tendency of both carpoolers and non-carpoolers to overestimate that savings. Figure 3.22 compares the average savings estimated by carpoolers and solo drivers in four District Four lanes with the actual time savings measured by CALTRANS.



Source: Origin/Destination Surveys in Eight Bay Area Corridors, SYSTAN, 1997

Figure 3.22 Estimated And Actual HOV Lane Time Savings (1997 Survey)

This 1997 survey found that, on the average, carpoolers in the four corridors thought they could save 16.1 minutes by using HOV lanes for their morning trip, more than double the average measured savings of 7.5 minutes. Solo drivers thought they might save 11.2 minutes, half again the actual savings. This tendency to overestimate the savings available from carpool lanes has been documented in survey after survey and undoubtedly makes the lanes appear more attractive to drivers than to statisticians comparing raw numbers. Thus there may be a psychological advantage in providing a carpool lane even when the available time savings appear minimal.

Carpool Formation. Another finding common to all of the surveys conducted among Bay Area ride-sharers involves the formation and composition of carpools. The vast majority of carpools are formed either with family members or co-workers. The percentage of carpools formed with these two groups has ranged from 75% to 87% in surveys conducted since 1990. Only about four percent of all carpoolers cited either "ridematching services" or "company carpool programs" when asked "How was your carpool formed?" In the Bay Area, the only sizable source of carpool companions rivaling family and co-workers occurs on the Bay Bridge, where significant numbers of drivers pick up "casual" riders at transit stops in the East Bay in order to bypass the $3.00 bridge toll and save an average of roughly 20 minutes at the toll plaza. Various surveys have found that between 36% and 48% of the carpools using the Bay Bridge HOV lanes during the morning peak are composed of "casual" carpoolers.

Violation Rates. Violation rates are low on the Bay Area's HOV lanes, averaging 6.9% overall. Violation rates are highest on those lanes with occupancy requirements of three or more persons per vehicle, because there are fewer legitimate carpoolers in these lanes to contribute to the denominator of the rate equation. For the most part, however, violation rates on District Four freeways are well below the ten percent threshold generally identified as a benchmark for concern.

Thanks to CHP enforcement policies and a high schedule of fines ($271 for a first offense), violation rates have been below the ten percent threshold for some time on District four's HOV lanes. Surveys in the early 90's show that drivers were aware of violations and tended to overestimate the extent the low rates. In general, drivers guessed that actual violation rates of 5% to 10% were in the 10% to 20% range, and before/after studies suggested that drivers were insensitive to rate changes below the 20% level. While drivers acknowledged that HOV lane occupancy violations were a problem, most considered them to be a minor problem. Even so, when asked, most drivers felt that HOV lane enforcement needed to be increased.

Carpool Longevity. One of the less-well-known but most important effects of carpool lanes is their impact on carpool longevity. A recent survey of Southern California drivers suggests that the life span of carpools nearly doubled in certain corridors in the years after HOV lanes were introduced. While Northern California lacks the pre-HOV-lane surveys needed to make this before/after comparison, certain of the driver surveys taken between 1995 and 1997 suggest that a similar phenomenon exists in Northern California. In these surveys, drivers using corridors with HOV lanes reported longer-running carpools than drivers in corridors with no HOV lanes, and where carpool longevity seemed to correspond with HOV lane longevity. In a survey of eight Bay area corridors made in 1997, drivers using the Bay Bridge reported the longest running carpools (4.6 years), well above the average duration of 3.6 years registered for other corridors which either had no HOV lanes or HOV lanes with a shorter life span than those on the Bay Bridge.

Self-Reported Impacts of HOV Lanes. In the series of surveys undertaken by SYSTAN between 1995 and 1997, drivers using corridors with HOV lanes wee asked whether the bus/carpool lanes in their corridor had caused them to change their driving patterns in any way. In all, 18% of the solo drivers and 52% of the current carpoolers responding said that the HOV lanes in their corridor had caused them to change their driving patterns. The predominant change reported by solo drivers was "I changed the time I drove" (reported by 11% of respondents), while the predominant change reported by carpoolers was "I formed a regular carpool" (reported by 22% of responding ridesharers). In general, the longer an HOV lane had been in operation, the more likely it was to induce reported changes.

Opinions on Operating Policies. In the most recent survey of Bay Area drivers, undertaken by DKS in 2002, nearly 80% of Web survey respondents opposed raising HOV lane occupancy requirements from 2+ occupants to 3+ occupants. Skepticism regarding 3+ occupancy requirements on Marin 101 was voiced by drivers in a 1988 focus group, when the lane was only carrying around 300 vehicles per hour during the morning peak. The consensus of participating drivers was, "Most of us think the darn thing isn't doing its job." Shortly after the focus groups, entry requirements were lowered to 2+ occupants, and lane utilization rose above 900 vehicles per hour during the morning peak.

3.3.6 District Four Summary

District Four's HOV lanes are well utilized during peak commute periods and have the support of the general public. They offer significant time savings to carpoolers, particularly those using the Bay Bridge, and in almost every instance the percentage of carpoolers in freeway corridors has increased, along with vehicle occupancy rates, following the introduction of the preferential lanes.

For the most part, there is no way of knowing whether the measured increases in carpooling on District Four's mainline HOV lanes came from newly formed carpools or existing carools which changed routes to take advantage of improved travel times. As time goes on, the question of whether the carpools added to the freeway mix following the introduction of HOV lanes were new or diverted becomes less and less important. If new, they represented an immediate improvement in the overall vehicle occupancy picture. If diverted, they filled space reserved to reward ridesharing behavior and freed up the space they left to relieve the congestion faced by non-carpoolers. Over time, there is evidence that the HOV lanes cause carpools to last longer, regardless of how they came to be in the lanes.

3.4 DISTRICT SEVEN

3.4.1 System Map

CALTRANS District Seven comprises the two Southern California Counties of Los Angeles and Ventura. As of December, 2003, the area had 422.6 directional miles of HOV lanes, including

- 400.6 directional miles of exclusive freeway lanes reserved for vehicles with two or more (2+) occupants on a 24/7 basis; and
- 22 directional miles of exclusive freeway lanes reserved for vehicles with three or more (3+) occupants during the peak am and pm traffic periods and 2+ occupants at other times (The El Monte Busway);

This network of HOV lanes is supported by a variety of exclusive connectors and feeder lanes, and park-and-ride lots, including

- One freeway-to-freeway HOV connector linking I-105 and I-110;
- 360 HOV bypass lanes at 870 metered freeway on-ramps and 19 metered freeway-to-freeway connectors; and
- 109 Park-and-Ride lots.

A map of existing HOV freeway routes appears in Figure 3.23.

3.4.2 HOV Freeway Inventory

Current Information Appendix D contains an inventory of HOV freeway lanes in District Seven. The inventory, assembled from data in the most recent (July 2004) District Seven HOV Report, lists routes and lane miles by direction, along with occupancy requirements, operating hours, opening dates, and dates and descriptions of subsequent modifications.

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Data Availability. Since HOV lanes were first introduced in Southern California with the creation of the Santa Monica Diamond Lanes in July 1976 and the introduction of carpools on the El Monte Busway in October 1976, CALTRANS District Seven has regularly recorded data on the exclusive lanes operating within district boundaries. Recorded data have included statistics on vehicle volumes and occupancies in HOV lanes and adjacent mixed flow lanes, as well as floating car runs documenting the time advantages provided by the HOV network. These statistics have been recorded annually (sometimes more frequently) and provide an invaluable resource for any analysis of HOV lane operations. In recent years, the assembled data have been accumulated in annual reports summarizing HOV operations, profiling individual lane configurations, and documenting the performance of HOV lanes and adjacent mainline lanes. Annual Reports for the years 2000 through 2003 were used in preparing this analysis.

In addition to the annual reports on HOV lanes prepared by District Seven, several project-specific and system-wide research reports have been prepared covering various HOV lanes in the Los Angeles area. A few of the more prominent are listed below.

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Source: District Seven Web Site

Figure 3.23 Map Of District Seven HOV Freeway Lanes

The Santa Monica Freeway Diamond Lanes: An Evaluation, SYSTAN, Inc. April 1977

San Bernardino Freeway Express Busway: Evaluation of Mixed-Mode Operations, Crain & Associates, July, 1978

TSM Project Violation Rates, Final Report, SYSTAN, Inc. June, 1979

Route 91 Artesia Freeway Operational Report, CALTRANS District 07, December, 1986

HOV Lane Violation Study, SYSTAN, Inc, January 1990

HOV Lane Safety, Cal Poly, September, 1992

Impacts of the SR 91 Value-Priced Express Lanes, Final Evaluation Report, Cal Poly, December 2000

HOV Performance Program Evaluation Report, Los Angeles County, PB Study Team, April 2002

Copies of these reports were assembled as background for the analysis of individual HOV projects in District Seven.

3.4.3 Historical System Performance

The following charts document various aspects of the year-by-year performance of the HOV lanes in CALTRANS District Seven from their inception to 2003.

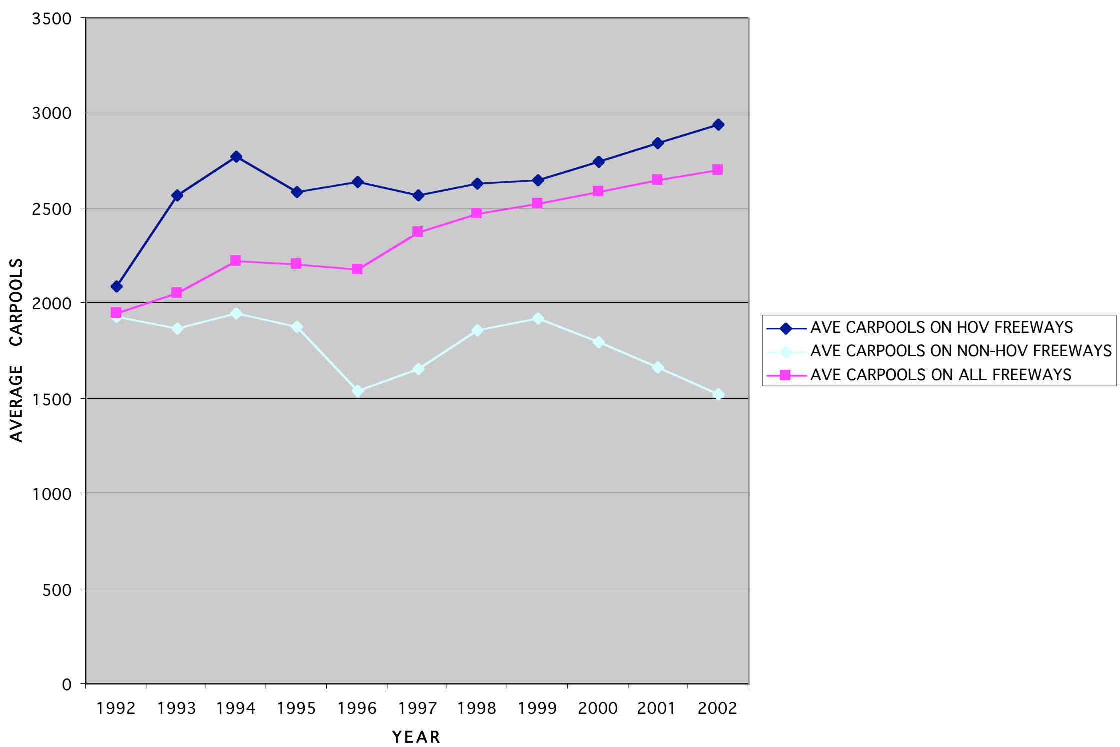

Figure 3.24 Carpools Over Time On HOV And Non-HOV Freeways (Caltrans District Seven: Two Peak Morning Hours)

Carpools on HOV and Non-HOV Freeways. Figure 3.24 plots the growth of carpools on HOV and non-HOV freeways in District Seven during the two peak morning hours between 1992 and 2003 (1). The figure shows an immediate growth in carpooling in the years 1993 and 1994, which saw 121.4

new HOV lane miles introduced on LA-91, I-105, I-210, and I-405. The average number of carpools on district freeways then leveled off, but began rising steadily between 1997 and 2003. [1]

The steady increase in carpooling between 1997 and 2003 was fueled almost exclusively by increases on freeways with carpool lanes, as Figure 3.24 shows a decline in the average number of carpools on non-HOV freeways over that same period.

Carpool Growth Before and After HOV Lanes. Figure 3.25 charts the growth in carpools following the introduction of HOV lanes on District Seven freeways. The figure shows a composite average for all District Seven HOV lanes introduced since 1992 and charts the average level of carpooling recorded during the peak two hours before preferential lanes were introduced, followed by the year-by-year growth in carpooling as the lanes matured.

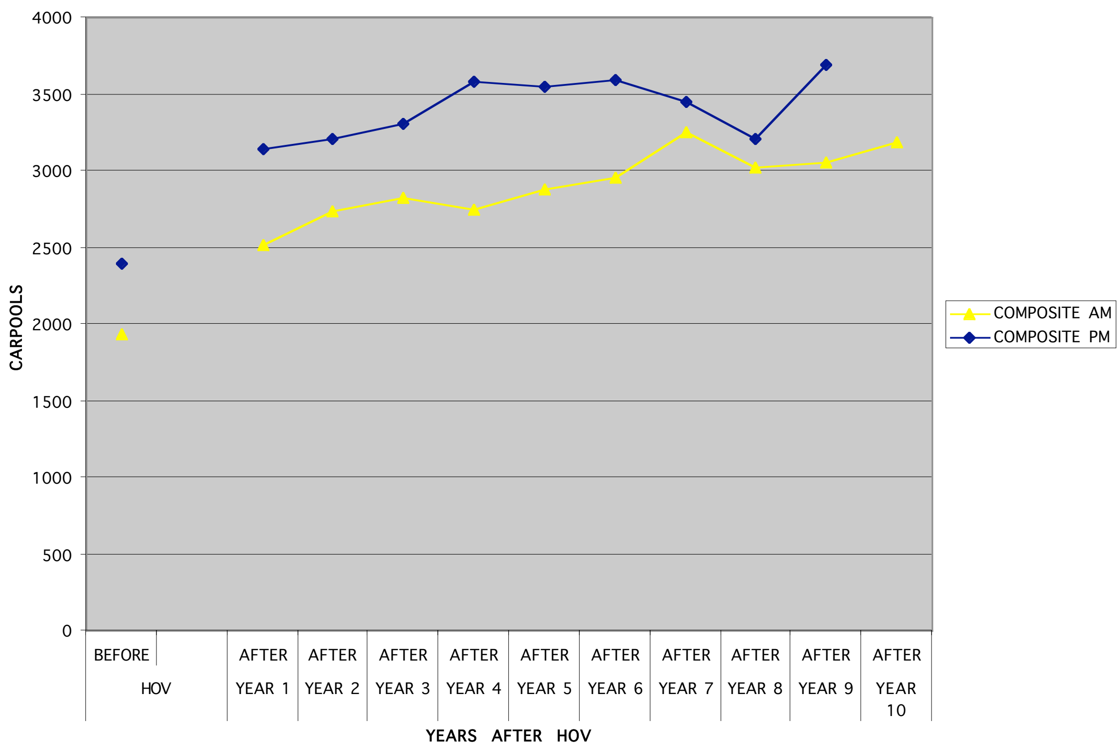

Figure 3.25 Carpool Levels Before And After HOV Lane Introduction (Caltrans District Seven: Peak Two Hours, AM and PM)

[1] NON-HOV Freeways: LA-2, I-5, LA-101, I-710, LA-14 (92-97), LA-57 (92-96), LA-60 (92-98), LA-91 (92), I-105 (92), I-110 (92-95), LA-118 (92-93), LA-134 (92-95), LA-170 ((92-95), I-210 (92), I-405 ((92), I-605 (92-96)

HOV Freeways: I-10, LA-14 (98-03), LA-57 (97-03), LA-60 (99-03), LA-91 (93-03), I-105 (93-03), I-110 (96-03), LA-118 (94-03), LA-134 (96-03), LA-170 96-03), I-210 (93-03), I-405 93-03), I-605 (97-03)

The chart shows an initial spurt in the incidence of carpooling immediately following the introduction of HOV lanes. During both morning and evening peaks, carpooling increased by 30% during the first year of HOV operations. Carpooling continued to increase steadily following this initial spurt, rising by 21% above the first-year level after nine years of lane operation during the morning peak, and by 17% over the same period during the evening peak.

Growth in Average Vehicle Occupancy. The steady growth in carpools shown in Figure 3.25 could simply reflect an overall increase in travel on Los Angeles freeways. A comparison of Average Vehicle Occupancy (AVO) rates over the period before and after the installation of HOV lanes, however, shows that the rate of carpooling has been increasing along with actual ridesharing levels. Figure 3.26 below summarizes the AVO in all lanes before, during, and after, the opening of District Seven HOV lanes.

2+ HOV ROUTES	BEFORE HOV IMPLEMENTATION	AFTER HOV OPENING	YEAR 2000	YEAR 2003
AM PEAK PERIOD	1.15	1.24	1.27	1.30
PM PEAK PERIOD	1.23	1.28	1.30	1.31

Figure 3.26 Average Vehicle Occupancy Across All Lanes

The figure confirms the initial spurt in vehicle occupancies following the opening of new HOV facilities, and shows that the subsequent increase in carpooling reflects an increase in Average Vehicle Occupancy as well as an increase in the sheer number of carpools.

3.4.4 HOV Lane Safety

The thorough analysis of District Seven HOV lanes undertaken by the PB Group for LACMTA (PB Group, 2002) compared accident rates on District Seven freeways two years before and one year after the opening of HOV lanes and concluded that

> …no distinct trends or patterns were identified that can be attributed directly to facilities with carpool lanes versus freeways without carpool lanes. In general, it was determined that accident rates on the facilities with carpool lanes are influenced by traffic congestion, vehicular mix and roadway conditions in the same way that these factors affected facilities without HOV lanes.

Although the study found "no distinct trends or patterns" in accident rates, fourteen of the twenty-four before/after pairings studied (58%) showed an increase in accident rates once HOV lanes had been introduced. Moreover, previous evaluations of specific HOV facilities on the Santa Monica and San Bernardino Freeways found that accidents increased markedly following the introduction of these early HOV installations (See Section 3.4.6).

The question of accident impacts remains one of the most vexing surrounding the implementation of HOV lanes. Since each of the recent District Seven HOV lane implementations studied by the PB group had been created by adding lanes to the freeway mix, causing an immediate reduction in congestion, the fact that no consistent accident rate increases were observed does not necessarily represent a clean bill of health for these installations. One would expect, for example, that the introduction of additional lanes might cause accident rates to decrease. The impact of HOV lanes on safety is an issue that merits additional research. More rigorous studies are needed to isolate the impacts of such features as limited access and egress, operating hours, and barrier-free operations on accident rates.

3.4.5 Current System Performance

The following charts offer lane-by-lane comparisons of such key performance measures as vehicle volumes, occupancies, travel time savings, and violation rates for the most recent year available, 2003.

Peak-Hour Traffic Volumes. Recent vehicle volumes on District Seven's HOV lanes are graphed in Figure 3.27, which shows peak-hour volumes in the peak direction of morning and evening flow.

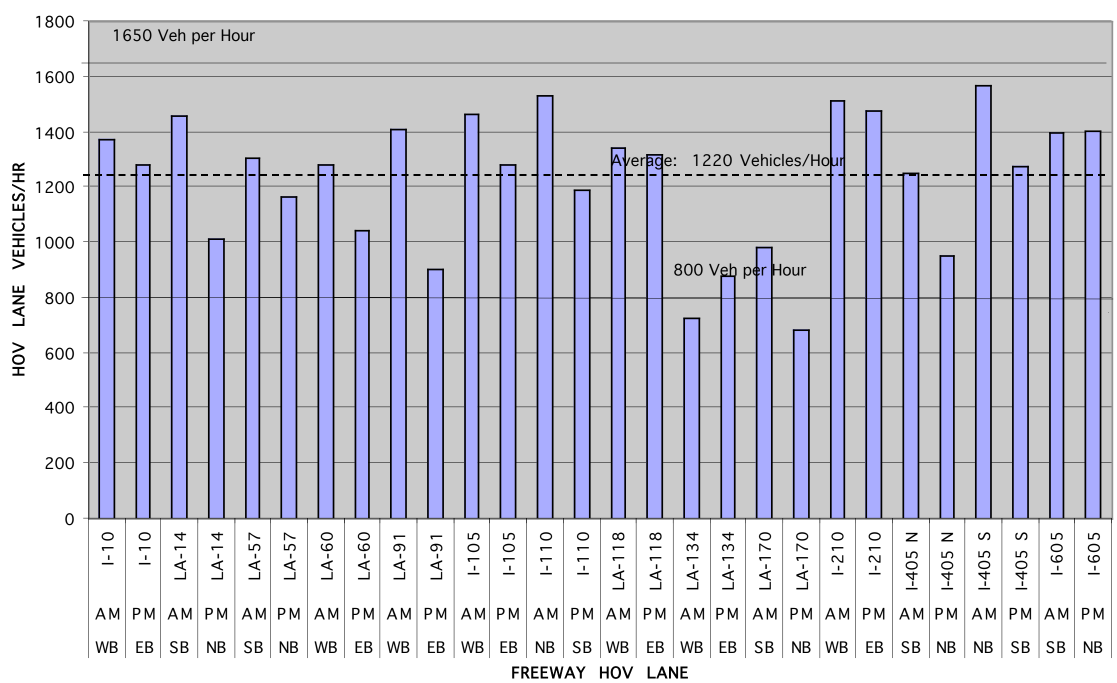

Figure 3.27 Peak Hour Vehicle Volumes, 2003

The horizontal lines of Figure 3.27 represent two generally recognized operating standards for HOV lanes.

1.) The lower level of 800 vehicles per hour, which is generally recognized as the minimum operating standard for a mature HOV lane (HOV Systems Manual, NCHRP Report 414). Operations below this level can experience the "empty lane syndrome" at which lanes appear underutilized; and
2.) The upper level of 1650 vehicles per hour, at which point free-flow operations can begin to deteriorate, causing the time advantage offered by the HOV lanes to disappear. (Parsons Brinckerhoff, 2002)

As indicated in Figure 3.27, with the exception of morning operations on LA-134 and evening operations on LA-170, all HOV freeway lanes in District Seven exceed the minimum operating standard of 800 vehicles per hour. The average peak hour flow on all District Seven HOV lanes is 1220 vehicles per hour, so there is little danger that the district's HOV lanes will fall victim to the "empty lane syndrome." In fact, at least three Interstate HOV lanes (I-110, I-210, and I-405) approached the upper limits of their capacity during the peak morning commute period.

Person Volumes. Figure 3.28 compares the percentage of freeway person trips carried by District Seven HOV lanes and adjacent mixed-flow lanes in the peak direction of flow during the peak morning and evening commute hours.

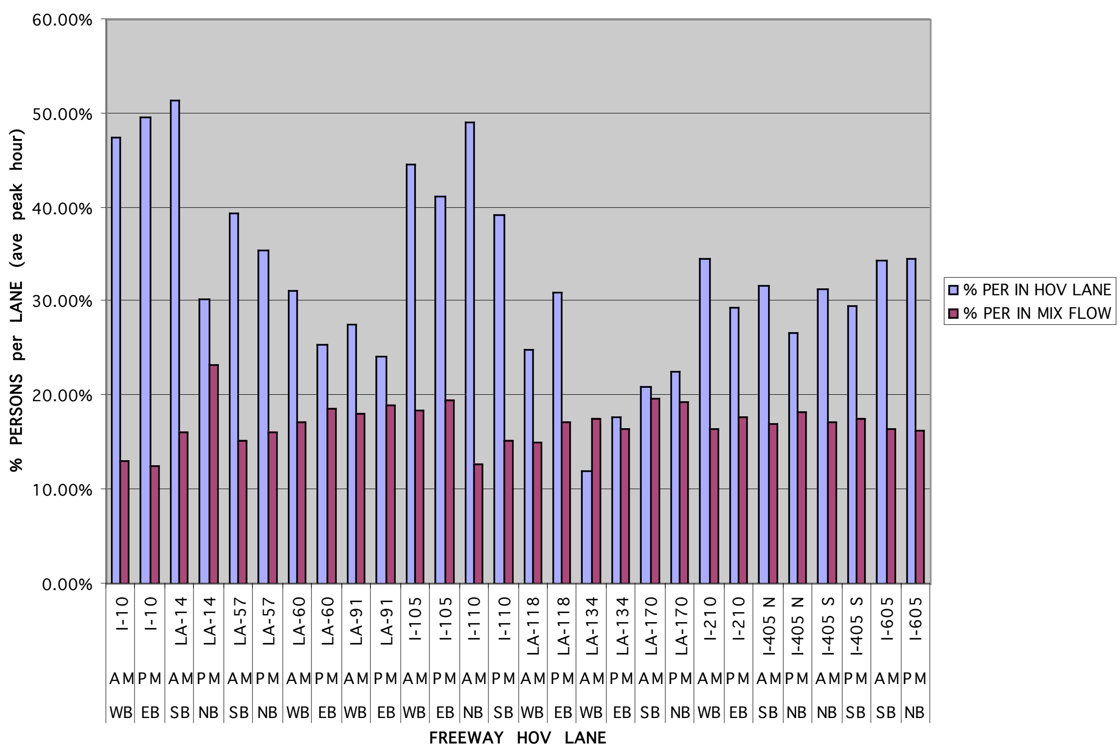

Figure 3.28 Percent Persons In HOV And Average Mixed-Flow Lanes (Caltrans District Seven, 2003: Peak Hour, Peak Direction)

As would be expected, in nearly every case, the percentage of freeway travelers carried by the HOV lanes is significantly greater than the percentage carried by the average adjacent mixed-flow lane. The single exception is the morning peak performance of the HOV lanes on LA-134. In all other cases, HOV lanes carry more people than the average adjacent mixed-flow lanes in both peak directions. On the average, HOV lanes carry 32.8% of the people in District Seven HOV corridors, while the average adjacent mixed-flow lane carries only 17.1%. Except on the El Monte Busway, where the HOV lane carried 50% of all people traveling on the freeway during the evening peak, the predominant person-carrying capacity of the HOV lanes is achieved through carpools, with relatively small contributions from buses.

Travel Time Savings. Figure 3.29 graphs the time savings available on each leg of District Seven's HOV freeway network. Time savings were calculated by comparing the travel times of vehicles traveling the entire length of individual HOV lanes with the corresponding times recorded by vehicles in adjacent mixed-flow lanes.

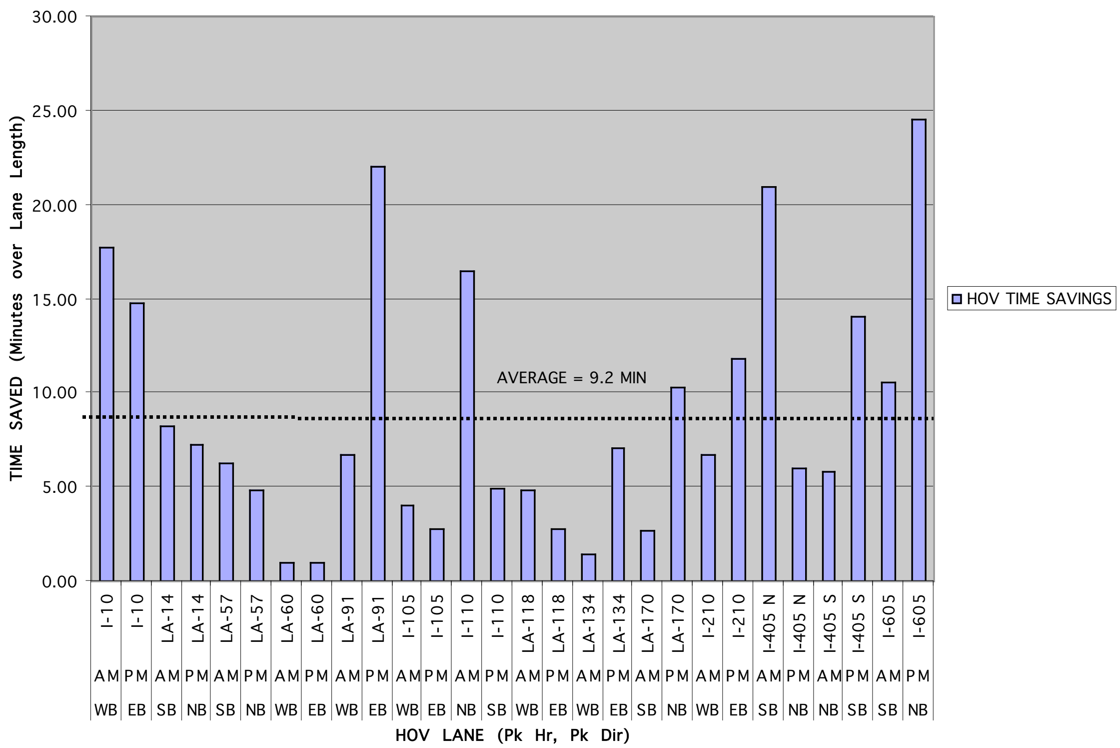

Figure 3.29 HOV Lane Time Savings
(Caltrans District Seven: Peak Hour, Peak Direction)

The HOV Systems Manual (NCHRP Report 414) suggests that a savings goal of five minutes per trip, and/or one minute per lane mile, be used to gauge the success of HOV lane operations. As shown in Figure 3.29, one direction are LA-60 and I-105. The average time savings for all District Seven HOV lanes recorded in 2003 was 9.2 minutes (0.62 minutes per mile), well above the five-minute success threshold defined in the HOV Systems Manual.

Violation Rates. Figure 3.30 plots the average violation rates recorded on District Seven's HOV lanes for the year 2003. In this case the violation rate is defined as the percentage of vehicles in the lane that fail to meet the minimum occupancy requirement.

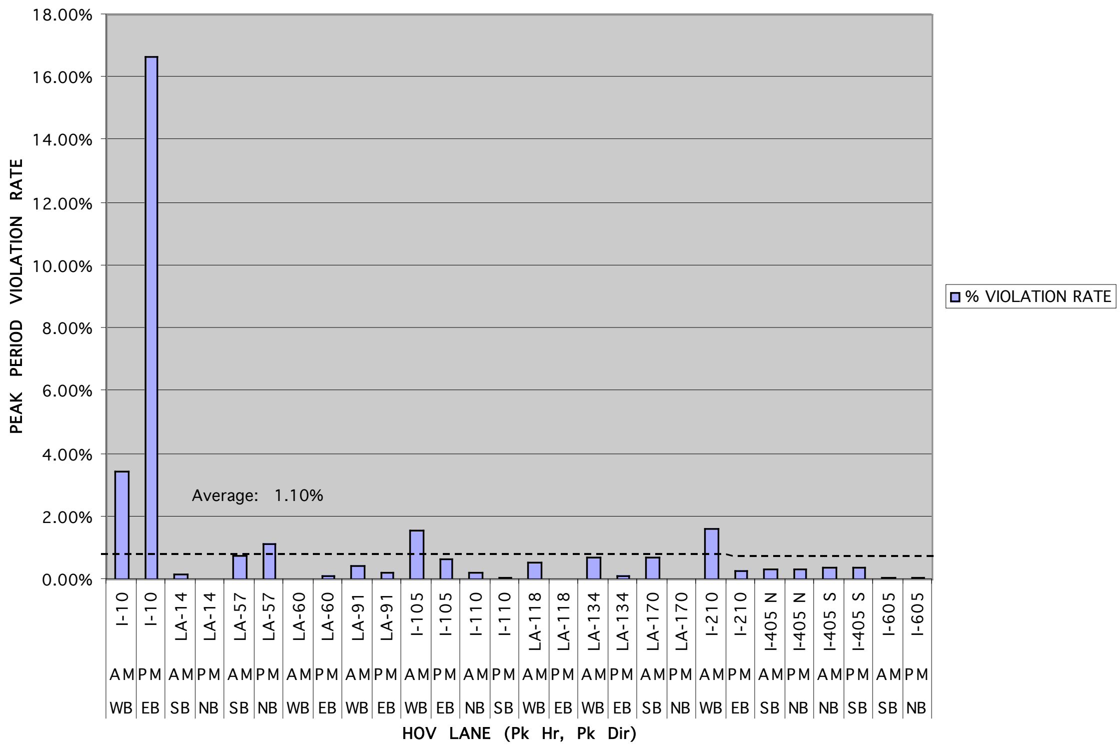

Figure 3.30 Violation Rates Per Lane
(Caltrans District Seven, 2003)

The average violation rate was 1.1%, well below the 10% rate identified in past studies (for example, Billheimer, 1990) as a threshold for concern. Only one set of District Seven HOV lanes, the lanes on the El Monte Busway, exceed this threshold, and no other set of lanes has a violation rate over 2%. The 3+ occupancy requirements on the El Monte Busway help to account for its high violation rates. While 3+ occupancy requirements raise the number of potential violators slightly, they also tend to raise violation rates more sharply, since there are fewer legitimate carpoolers in the lane to contribute to the denominator of the rate equation. If the El Monte Busway's 3+ lanes are ignored in computing an average violation rate, the District-wide violation rate for lanes with 2+ occupancy drops to 0.4%, less than half the overall average.

3.4.6 Two Ground-Breaking Projects

CALTRANS District Seven was the site of two ground-breaking HOV projects in the mid-1970s. Both occurred on stretches of I-10. To the west of Los Angeles, the controversial Santa Monica Diamond Lanes were introduced in March, 1976, while, to the east of the city, the El Monte Busway was opened to buses early in 1973 and to carpools with three or more occupants in October 1976.

Santa Monica Freeway Project Overview. On March 15, 1976, CALTRANS reserved the median lane in each direction of a 12-mile, eight-lane segment of the Santa Monica Freeway linking the city of Santa Monica with downtown Los Angeles for the exclusive use of buses and carpools carrying three or more occupants during the peak hours of traffic flow. Implementation of the Diamond Lanes was accompanied by the introduction of a variety of express bus services and the opening of three new Park-and-Ride lots in Western Los Angeles.

The Santa Monica Freeway project marked the first time preferential lanes had been created by taking busy freeway lanes out of existing service and dedicating them to the exclusive use of high-occupancy vehicles. Although the Diamond Lanes entailed no major physical modifications or construction on the freeway itself, they generated considerable emotional reaction among freeway drivers and other residents of Los Angeles. The first day of operations was disastrous, featuring bumper-to-bumper traffic, long queues at on-ramps, a malfunctioning ramp meter, many accidents, outraged drivers, poor press notices, and derisive news commentary. As the project progressed, freeway performance improved somewhat and both bus and carpool ridership increased, but accidents remained a serious problem and the climate of public opinion and media reaction grew more and more hostile. The preferential lanes operated amid much controversy for 21 weeks until August 9, 1976, when the U. S. District Court in Los Angeles halted the project and ordered additional environmental studies prior to its continuation.[2]

Santa Monica Freeway: Positive and Negative Impacts. Much of the controversy surrounding the Santa Monica Diamond Lanes consisted of conflicting claims regarding the ability of the project to accomplish its stated objectives of conserving energy, improving air quality, and expanding effective freeway capacity by increasing the occupancy of buses and automobiles using the freeway. The independent D. O. T. analysis (Billheimer, et al, 1977) of the vast quantities of data assembled by both friends and foes of the project revealed that, although some of the stated objectives had been attained by the close of the demonstration, the cost in accidents, driver delay, and public outrage was far greater than anyone had anticipated. Major findings of that analysis are summarized below.

On the positive side of the ledger:

- During the last seven weeks of the project, the Santa Monica Freeway carried 1.8% fewer people in 10.1% fewer automobiles than it had carried prior to the project in the morning and evening peak periods. The entire corridor, including parallel surface streets, carried 1% more people in 5% fewer vehicles.

- The number of 3+ carpools on the freeway increased by 65% during the project.

- In response to both the Diamond Lanes and a significant increase in transit routes and service frequency, daily bus ridership between the Westside study area and the Los Angeles CBD more than tripled, increasing from 1,171 riders per day prior to the project to 3,793 riders per day during the last week of the Diamond Lane operation.

- Speeds recorded by carpoolers in the Diamond Lanes were both faster and more consistent than pre-demonstration speeds. Carpoolers traveling the length of the Diamond Lanes were able to save between two and three minutes over pre-project travel times and approximately five or six minutes over travel times in other lanes.

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[2] A detailed account of the project's impacts may be found in the independent evaluation undertaken by SYSTAN, Inc. for the U. S. Department of Transportation (Billheimer, et al, 1977)

However, certain hoped-for benefits failed to materialize during the short project life:

- After an initial increase, fuel consumption levels on the freeway and adjacent city streets dropped slightly during the last seven weeks of the project, falling an estimated 0.8% below pre-project levels.

- Estimates of vehicle emissions made on the basis of mileage computations indicated that emissions increased early in the project and dropped to pre-project levels by the close of the demonstration.

Moreover, the positive and neutral impacts of the project were counterbalanced by the following negative considerations:

- Freeway accidents rose markedly during the project. An average of 25 accidents per week occurred during Diamond Lane operating hours, roughly 2.5 times the weekly pre-project average.

- During the Diamond Lane demonstration, freeway speeds for non-carpoolers were both slower and less predictable than they were before the demonstration. Although speeds improved as the demonstration progressed, freeway driving time for non-carpoolers traveling the full length of the project over the last seven weeks of the demonstration were slightly more than one minute longer than pre-project levels in the westbound direction during the P.M. peak and more than four minutes longer in the eastbound direction during the A.M. peak.

- Average delays at the busiest metered ramps increased between one and five minutes per car during the peak hours of morning and evening operations.

- Aggregate travel speeds on surface streets paralleling the freeway slowed slightly during the demonstration, dropping by about 4.5%.

- The weight of the media and public opinion were solidly against the project. Eighty-six percent of corridor drivers surveyed, including the majority of carpoolers, felt that the Diamond Lanes were either harmful or of no benefit whatsoever.

After the close of the demonstration, conditions on the freeway approximated those experienced prior to the project. Although bus service continued and bus ridership remained high, at more than two-and-one-half pre-project levels, the number of carpools dropped to within 5% of the number on the freeway before the Diamond Lanes were implemented.

Santa Monica Freeway: Impact Summary. Thus, the Santa Monica Freeway Preferential Lane project succeeded to some degree in attracting riders to carpools and transit, and increased freeway capacity with a minimum amount of additional construction and enforcement costs. However, the project brought about a significant increase in freeway accidents; energy savings and air quality improvements were insignificant; non-carpoolers lost far more time than carpoolers gained; and a heated public outcry developed which delayed the implementation of other preferential treatment projects in Southern California and gave planners and public officials in other areas ample cause for reflection before attempting to implement similar projects.

El Monte Busway: Project Overview. In the early 1970s, CALTRANS and the Southern California Rapid Transit District jointly implemented an HOV facility running 11 miles from downtown Los Angeles eastward along the San Bernardino Freeway (I-10) to the community of El Monte. The two unidirectional busway lanes were built in the median strip at the westernmost end of the project, and on a rail right-of-way adjacent to the freeway along the easternmost end closest to downtown. A one-mile extension into the downtown area was completed in 1989. The two-way facility includes both a five-mile segment separated from the mixed flow traffic by a concrete barrier (along the old railroad right-of-way) and a seven-mile segment separated by a painted buffer.

The busway was built with on-line stations, park-and-ride facilities and feeder bus lines, and opened to bus service in February 1973. Over the first thirty months of operations, bus ridership grew steadily from 1,000 daily passenger trips to 14,500 daily trips. Ridership then stabilized until August 1976, when SCRTD experienced a strike. During the strike, the facility was opened to authorized 3+ carpools that obtained and displayed an operation permit. When the strike was settled in October 1976, the requirement for a permit was dropped, and all 3+ carpools were allowed to use the busway.

El Monte Busway: Carpool Growth. The first eighteen months of mixed-mode (carpools plus buses) busway operations saw the number of carpools on the freeway double, an increase of at least 800 carpools. An evaluation of mixed-mode operations undertaken by Crain & Associates (Crain, 1978) showed that the additional carpools were "…newly formed and not caused by diversion from parallel roadways." Over the same period, bus ridership climbed to 18,000 trips per day.

The number of carpoolers using the San Bernardino Freeway has continued to grow over time following the opening of the El Monte Busway to mixed-mode operations. CALTRANS counts in 2002 showed that the number of carpools on the freeway during the two peak morning commute hours had increased by 277% over the number counted in 1976 just prior to the introduction of carpools on the busway. A similar comparison for the two peak evening commute hours showed that 3+ carpools had increased by 334% over the same period.

By 2002, the number of people in carpools and vanpools on the busway surpassed the number of bus riders, and the total number of ridesharers in the HOV lanes easily eclipsed the number of people using the average adjacent mixed-flow lane. During the peak hour of morning operations, CALTRANS counted 6337 people in the westbound HOV lanes, more than 3.5 times the number observed in the average mixed-flow lane. This impressive ratio held during the peak evening hour, when the eastbound HOV lane carried 5212 travelers, as compared with 1429 in the average adjacent lane.

El Monte Busway: Occupancy Requirements. On January 1, 2000 Senate Bill (SB) 63 lowered the occupancy requirement on the busway from 3+ to 2+ per vehicle, against the advice of both CALTRANS and the LACMTA. The two agencies cited studies showing that the resulting shifts would have a detrimental effect on busway operations. These fears proved to be justified. The change attracted too many users to the HOV lane and caused "…considerable congestion to peak hour traffic" (Caltrans Annual HOV Report, 2003). As a result, AB 769 overrode SB 63 and restored the 3+ occupancy requirements during peak hours. The 3+ requirement is currently in effect Monday through Friday from 5-9 a.m. and 4-7 p.m.

El Monte Busway: Impact Summary. The El Monte Busway represents one of the most successful HOV projects in Southern California. Ridesharing on the San Bernardino Freeway has grown steadily over the life of the project, and the busway lanes currently carry 3.5 times as many people as the average adjacent mixed-flow lane. Even though mixed-flow operations on the busway lanes were introduced at the same time that the Santa Monica Diamond Lanes were generating unfavorable publicity, the Busway remained uncontroversial and public support for the project has always been strongly positive. The early evaluation of mixed-mode operations (Crain, 1977) found that "the busway was superior to the additional freeway lane operation at reducing user costs, improving level of service, reducing environmental impacts, and providing for future contingencies." The only down-side to mixed-mode operations was an increase in accident rates on the buffer-separated access lanes at the eastern end of the project. There were no accident problems on the physically separated western portion of the busway.

3.2.7 Public Opinion

Introduction. Driver attitudes, perceptions, and opinions provide an important prism for viewing and evaluating high-occupancy vehicle lanes. In Southern California' District Seven, public attitudes have undergone a remarkable change, from heated opposition to HOV lanes in the wake of the disastrous experiment on the Santa Monica Freeway to wide-ranging support of the current area-wide network

It is instructive to trace the attitudes of District Seven drivers toward HOV lanes as revealed in focus groups and surveys conducted over the period of nearly thirty years since preferential lanes were first introduced on the Santa Monica Diamond Lanes and El Monte Busway. Driver surveys were conducted for a variety of purposes over this period, but the different surveys had enough in common to provide a glimpse of driver attitudes toward such issues as perceived time savings, carpool formation, violation rates, and general support for the HOV concept. Some of the key surveys of District Seven drivers that have focused on HOV issues are listed below in chronological order.

YEAR	REPORT	SPONSOR	FIRM	SURVEY TYPE	TARGET
1975	San Bernardino Busway Evaluation	CALTRANS	Crain	Rider Survey, Telephone	CP+Solo
1977	Santa Monica Diamond Lane Evaluation	DOT	SYSTAN	Mailback	CP+Solo
1981	TSM Project Violation Rates	CHP, CALTRANS	SYSTAN	Focus Groups, Mailback	CP+Solo
1990	HOV Lane Violation Rates	CALTRANS	SYSTAN	Focus Groups, Mailback	CP+Solo
2002	HOV Lane Performance Evaluation	LACMTA	PB Group	Focus Groups, Mailback, Telephone, Rider Survey	CP+Solo

HOV Lane Support. Support for HOV lanes among District Seven Drivers is currently positive. In a 2001 telephone survey undertaken as part of an HOV Performance Program Evaluation Report sponsored by LACMTA, the PB Group found that fully 88% of the survey respondents expressed support for carpool lanes. Only 8% opposed the concept, while 4% expressed no opinion. This represents a remarkable change in attitudes since 1976, when a telephone survey following the disastrous Santa Monica Diamond Lane experiment found that only 14% of the Los Angeles residents surveyed supported the concept of carpool lanes.

The recent PB group survey found that "Los Angeles County residents had mixed perceptions regarding the perceived utilization of District Seven carpool lanes." Forty-two percent of the residents surveyed felt that the lanes were under-utilized, while 37% thought the utilization level was about right. Only 8% of those surveys felt that the county's carpool lanes were over-utilized.

Perceived Time Savings. A common thread in all survey results, from the earliest to the most recent, is the agreement that HOV lanes save time for carpoolers and the tendency of both carpoolers and non-carpoolers to overestimate that savings. In their 2001 survey of Los Angeles residents, the PB group found that survey respondents reported an average time savings of more than 19 minutes during the a.m. peak period and 24 minutes during the p.m. peak. By way of contrast, the most recent savings reported by District Seven's Annual HOV Reports were 9.33 minutes during the a.m. peak and 8.65 minutes during the p. m. peak. These savings reflect the weighted average of actual measurements made over all HOV lanes in the District.

There are many reasons why the perceived time savings reported by drivers consistently exceed the actual measured time savings. Perceived savings can include savings realized from using bypass lanes on freeway on-ramps and/or HOV lanes on freeway-to-freeway interchanges as well as the savings on mainline HOV lanes. In addition, a single trip may include carpool lanes on several different freeway segments. Moreover, the savings reported by drivers may reflect the worst-case conditions for travel time in the adjacent mixed-flow lanes. Whatever the reason, this tendency to overestimate the savings available from carpool lanes has been documented in survey after survey and undoubtedly makes the lanes appear more attractive to drivers than to statisticians comparing raw numbers.

Carpool Composition. Another finding common to all of the surveys conducted among Southern California ride-sharers involves the formation and composition of carpools. The vast majority of carpools are formed either with family members or co-workers. In the 2001 survey conducted by the PB Group for LACMTA, an estimated 91% of all carpool lane users reported that they had formed their carpools either with family members (54%) or co-workers (37%). In the same survey, respondents indicated that coworkers comprised 85% of all vanpool users, with family members accounting for an additional 8%.

Reactions to Toll Lanes. In the 2001 mailback survey sponsored by LACMTA, 32% of the responding mixed-flow lane users supported the concept of allowing vehicles with only one occupant to use carpool lanes for a toll. An additional 48% were opposed to this idea. On the other hand, only 16% of the carpool lane users surveyed supported the idea of allowing toll-paying Single Occupant Vehicles to use carpool lanes, while 67% opposed the concept.

Reactions to Occupancy Restrictions. Three different focus group meetings were conducted in support of the HOV Performance Program review conducted by the PB Group for LACMTA in 2001. None of the groups supported an increase in the minimum carpool occupancy requirements from 2+ to 3+ unless there was clear evidence that the lanes had become over-utilized. Participants opposed allowing single-occupancy vehicles (SOVs) to use carpool lanes at any time.

3.4.8 District Seven Summary

District Seven's HOV lanes offer significant time savings to carpoolers and are well utilized during peak commute periods. On the average, carpoolers can save 9.2 minutes per trip traveling the length of the lanes. Violation rates are insignificant, averaging 1.1% throughout the District. Carpooling rates have consistently increased on affected freeways following the implementation of HOV preferences, and public support has grown remarkably after the disastrous introduction to the concept represented by the Santa Monica Diamond Lanes. Fully 88% of the respondents to a 2001 telephone survey expressed support for carpool lanes.

3.5 DISTRICT EIGHT

3.5.1 District Map

CALTRANS District Eight covers Riverside and San Bernardino Counties in Southern California. As of December 2000, the area had 91.2 directional miles of HOV lanes reserved for vehicles with two or more (2+) occupants. This network of HOV lanes connects seamlessly with the networks of neighboring Los Angeles and Orange Counties (CALTRANS Districts Seven and Twelve, respectively).

A map of existing HOV freeway routes in Southern California appears in Figure 3.31.

3.5.2 HOV Freeway Inventory

Current Information Appendix D contains an inventory of HOV freeway lanes in District Eight. The inventory, assembled from data in the District Eight 2000 Annual HOV Lane Report, lists routes and lane miles by direction, along with occupancy requirements, operating hours, opening dates, and dates and descriptions of subsequent modifications.

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Data Availability. In the late seventies and early eighties, when HOV lanes were first introduced in Southern California, each new lane was accompanied by an elaborate process of data collection that documented not only the number of vehicles in the lane, but also time savings, violation rates, and accident impacts. Unfortunately, this extensive process of data collection did not survive into the nineties. For example, vehicle occupancy counts were not regularly made in District Eight until the late 1990s. Even when occupancy counts were made, moreover, travel times and time savings in the HOV lanes were rarely documented.

In the late 1990s, Caltrans District Eight began assembling annual reports summarizing HOV operations and documenting the vehicle-and person-carrying performance of HOV lanes and adjacent mainline lanes. This activity was not pursued on a regular basis, and the inventory descriptions from the Year 2000 annual report were used in preparing this document. System descriptions were augmented with District Eight roadside counts from the year 2005, so that the most recent data available were used in developing the current analysis. While these counts documented vehicle throughput and occupancies in HOV and adjacent lanes, recent statistics on HOV travel times in the system were unavailable. Current travel times on mainline lanes, however, are available through the PeMS system.

Related Reports. In addition to the annual reports on HOV lanes prepared by District Eight, a recent report sponsored by the Southern California Association of Governments (SCAG) addressed the issue of HOV lane performance in Riverside and San Bernardino Counties (SYSTAN, June, 2005). Findings of this report were reviewed as background for the analysis of individual HOV projects in District Eight.

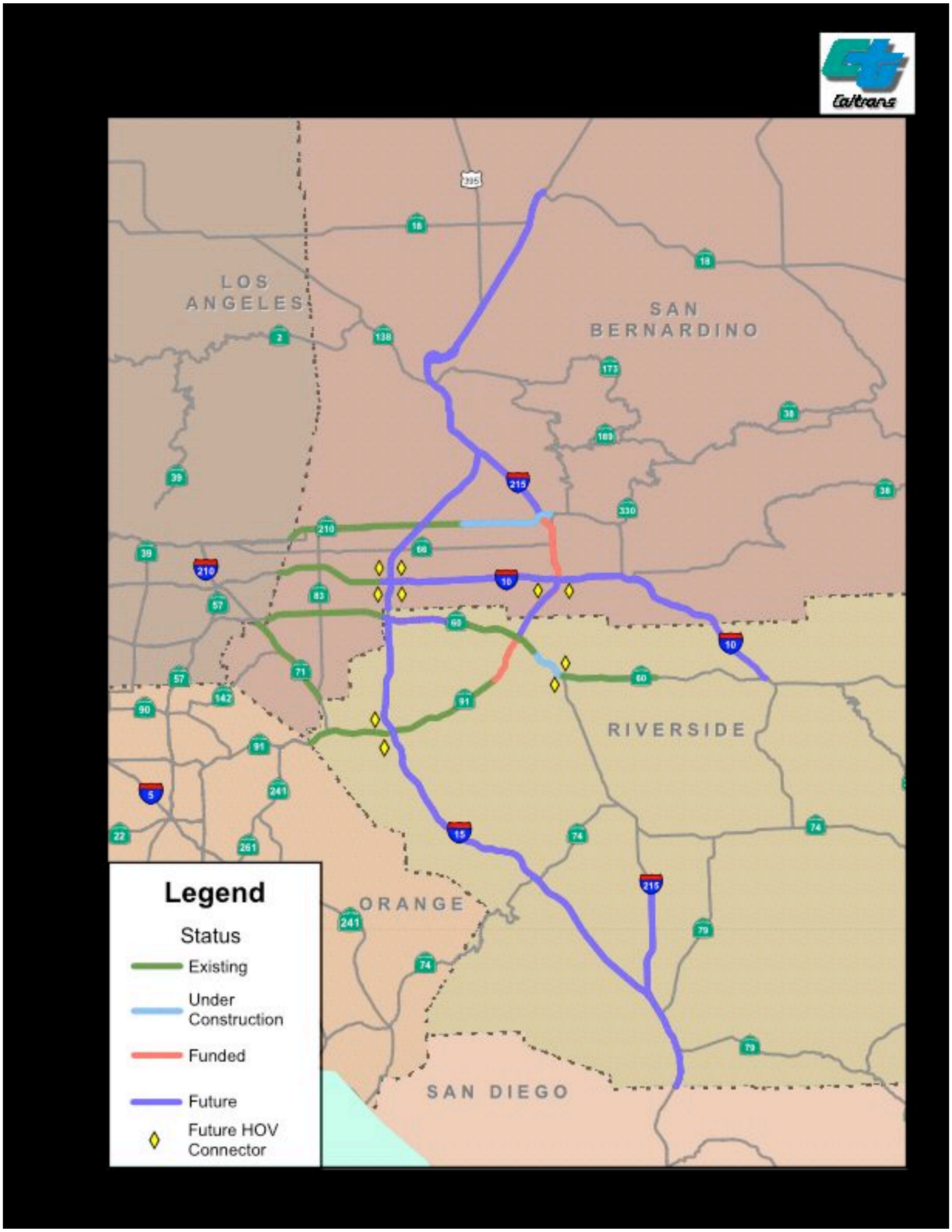
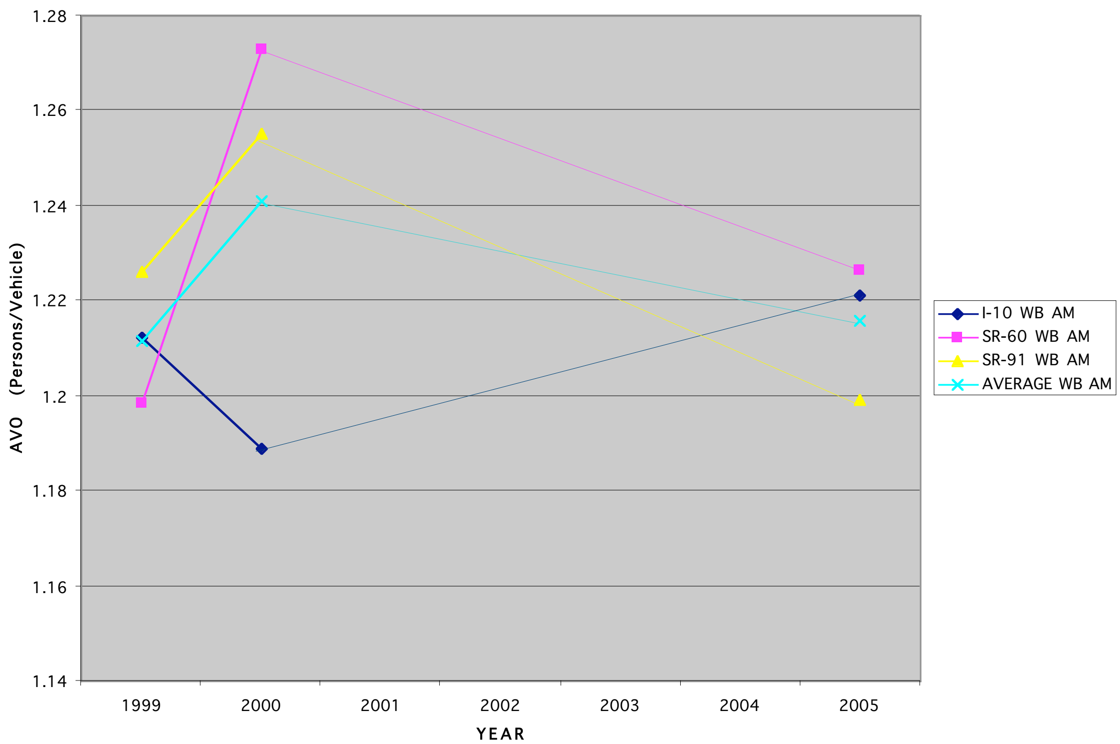


Figure 3.31 Map Of District Eight HOV Freeway Lanes

3.5.3 Historical System Performance

Average Vehicle Occupancy (AVO). Figure 3.32 documents the performance of the major HOV lanes in CALTRANS District Eight between 1999 and 2005 in terms of Average Vehicle Occupancy (AVO). AVO in the westbound direction for the three major east-west arteries in the District, I-10, SR-60, and SR-91, are plotted for the years 1999, 2000, and 2005. On the average, the AVO on these routes increased from 1.21 to 1.24 persons per vehicle to between 1999 and 2000, before dropping back to 1.22 persons per vehicle in 2005.



Source: District Eight 2000 Annual HOV Report, 2005 freeway counts

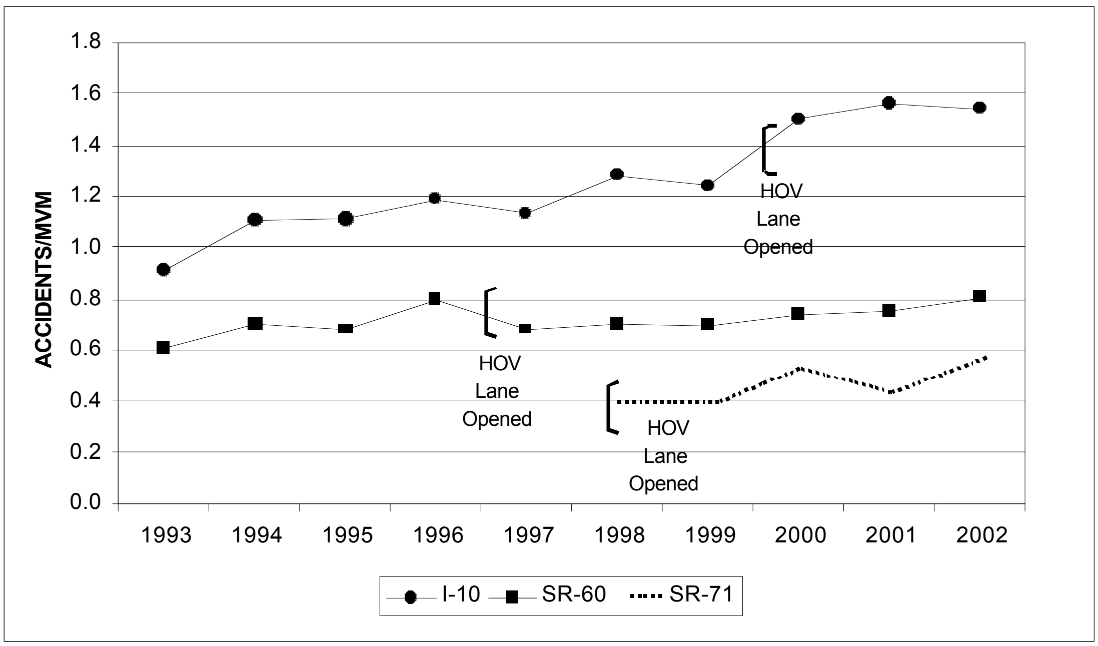
Figure 3.32 Average Vehicle Occupancy Over Time (Caltrans District Eight: 1999 TO 2005)

Since no effort was made to document the AVO on District Eight freeways prior to the installation of HOV lanes, there is no basis for documenting the impact of the lane implementation on ridesharing habits. On the average, the years between 1999 and 2005 saw a slight but insignificant increase in AVO on those east-west freeways with HOV lanes.

3.5.4 HOV Lane Safety

San Bernardino Interstate 10 Lanes. Figure 3.33 contains a graph of historical accident rates on three mainline HOV lanes in San Bernardino County: I-10, SR-60, and SR-71. The HOV lane on Interstate 10 stretches nearly ten miles from the LA County Line to Milliken Avenue and was opened in January 2000. The graph of Figure 3.33 shows that the accident rate on the affected stretch of freeway increased significantly after the lanes were opened and has continued at a higher rate ever since. In all, accident rates in the three years following the introduction of the HOV lane have been 35% higher than the rates experienced during the seven previous years.

San Bernardino State Route 60. Figure 3.33 also plots accident rates on SR-60 in San Bernardino, which parallels I-10 and stretches ten miles between the LA County line and Milliken Avenue. The HOV lane on SR-60 was opened on January 1997. The opening of the lanes did not cause a significant change in the accident rate over the affected stretch of freeway.



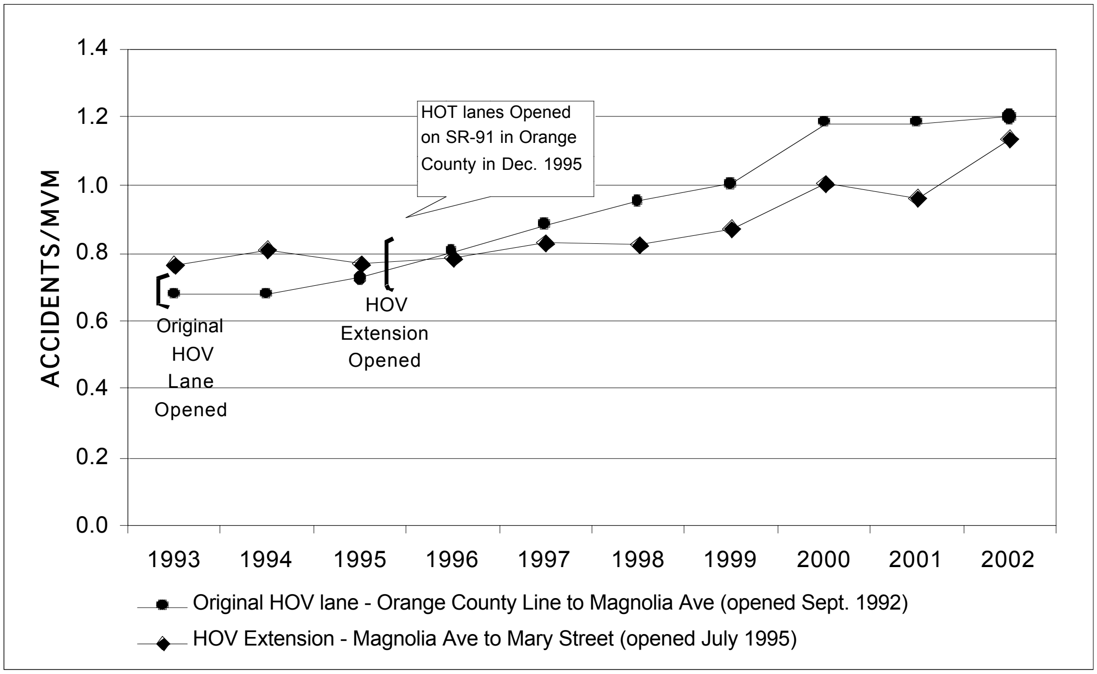
Source: TASAS, SYSTAN, June 2005.

Figure 3.33 Accident Rates On San Bernardino County Freeways With HOV Lanes

San Bernardino State Route 71. State Route 71 in San Bernardino was opened for southbound traffic in January 1998 and to northbound traffic in October of that same year. The HOV lanes were opened at the same time the new freeway was built, so that there are no before/after accident statistics. Accident rates on SR-71 are lower than those recorded on any of the other routes studied in Orange, San Bernardino, and Riverside Counties, presumably reflecting lower congestion levels and lower levels of HOV lane utilization.

Riverside Route 91. Figure 3.34 plots year-to-year accident rates for two stretches of HOV lanes on Route 91 in Riverside County. The first stretch covers the 11.2 mile length of road between the

Orange County line and Magnolia Avenue, opened in September 1992 and the second covers the 6.2 mile extension from Magnolia Avenue to Mary Street, opened in July 1995.



Source: TASAS, SYSTAN June 2005

Figure 3.34 Accident Rates On Riverside State Route 91

Figure 3.34 shows that there has been a steady increase in accident rates on both segments of Riverside SR-91 over the past ten years, with a particularly pronounced rise since January 2000. The increase appears to be unrelated to the introduction of HOV lanes on the two segments. However, in his study of the SR-91 HOT lanes in Orange County (Sullivan, December 2000), Ed Sullivan noted a statistically significant increase in peak period accidents on the two mile stretch of Riverside SR-91 just east of the HOT lanes immediately after the opening of the HOT lanes in December 1995. He attributes the increase to "...the increased congestion on the highway section after the (SR-91 HOT lanes) opened."

The steady increase in accident rates on both segments of Riverside SR-91 undoubtedly reflects increasing congestion levels near the Orange County line. In its Annual HOV Report for 2000, CALTRANS District Eight personnel note that:

> "The completion of the toll road facility (within the SR-91 Right of Way) in Orange County has not eliminated congestion within District 8. Continued monitoring has reflected no decrease in the westbound morning nor the eastbound afternoon congestion between the I-15/SR-91 Separation and the Orange/Riverside County line.

There still exists a bottleneck in traffic for the westbound traffic at the county line."

3.5.5 Current System Performance

The following charts offer lane-by-lane comparisons of such key performance measures as vehicle volumes, occupancies, travel time savings, and violation rates for the most recent year available, 2005.

Peak-Hour Traffic Volumes. Recent vehicle volumes on District Eight's HOV lanes are graphed in Figure 3.35, which shows peak-hour volumes in the peak direction of morning and evening flow at several different locations.

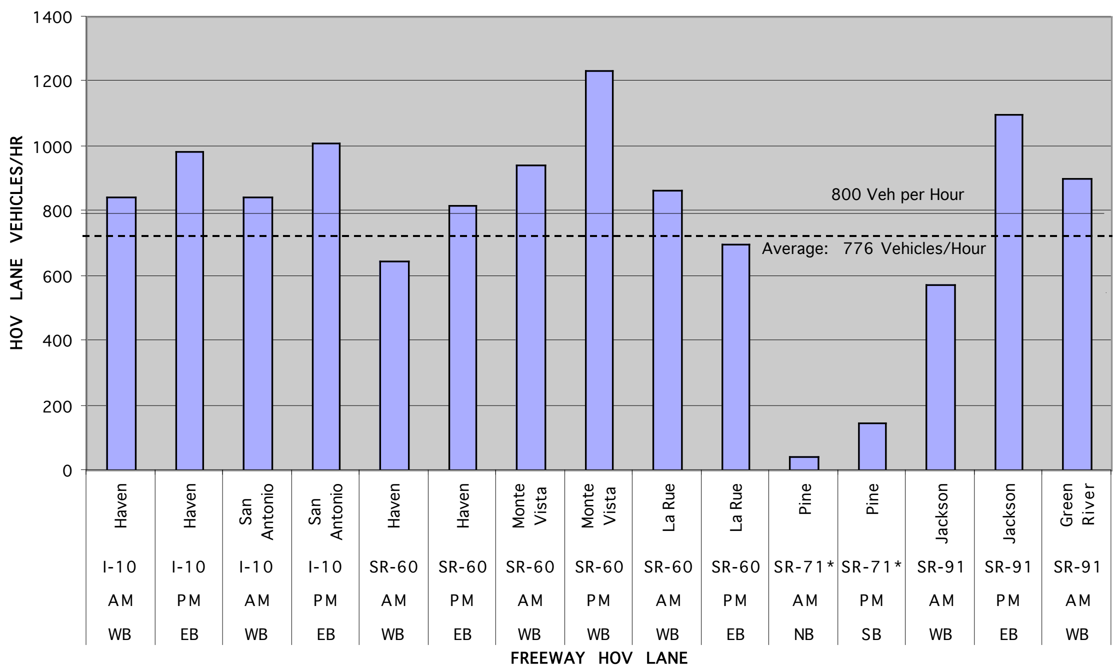


Figure 3.35 Peak Hour Vehicle Volumes, 2005
(Caltrans District Eight)

The bold horizontal line of Figure 3.35 marks 800 vehicles per hour, the generally recognized minimum operating standard for a mature HOV lane (HOV Systems Manual, NCHRP Report 414). Operations below this level can experience the "empty lane syndrome" at which lanes appear underutilized.

As shown in Figure 3.35, the HOV lanes in District Eight meet or exceed the minimum operating standard of 800 vehicles per hour in at least one direction for every freeway observation point with one exception. The single exception is the north/south freeway SR-71, where mixed-flow lanes are relatively uncongested and the HOV lanes offer no time advantage. (Due to the lack of current counts on this freeway, the information plotted in Figure 3.35 for SR-71 reflects information from District Eight's Annual Report for Year 2000). Largely because the utilization rate for SR-71 is so low, the average volume for the HOV lanes plotted in Figure 3.35 is 776 vehicles per hour, slightly below the minimum standard.

<u>Person Volumes</u>. Figure 3.36 compares the percentage of freeway person trips carried by District Eight HOV lanes and adjacent mixed-flow lanes in the peak direction of flow during the peak morning and evening commute hours.

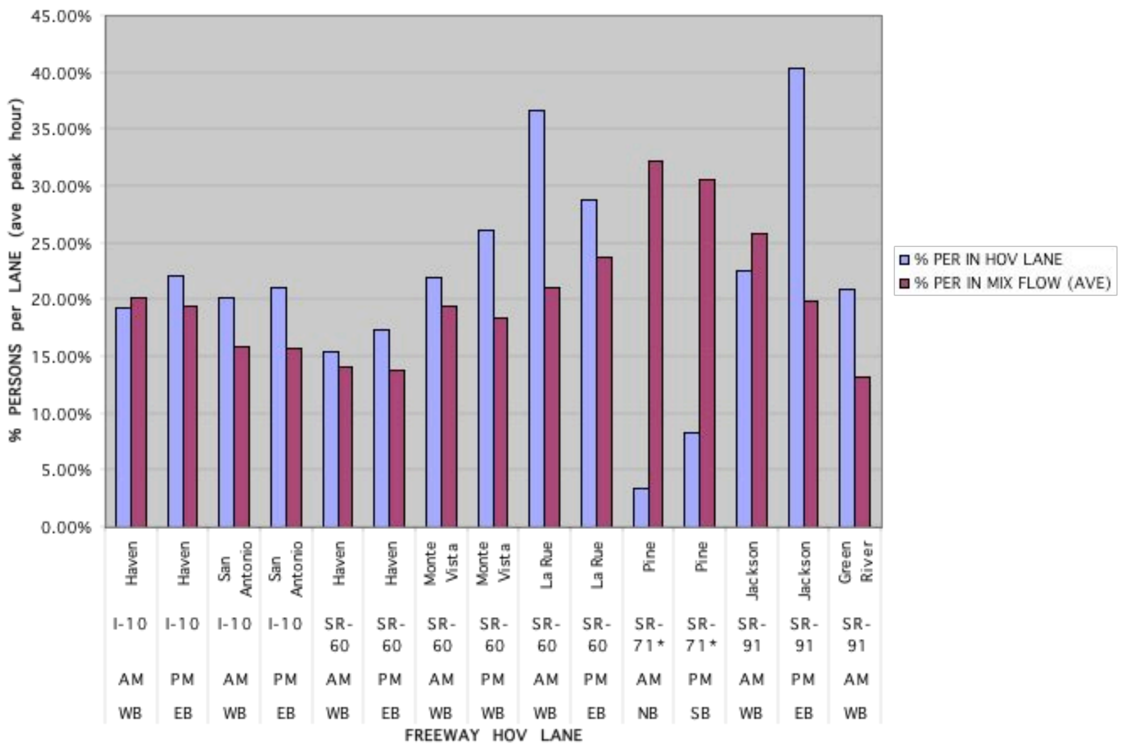


Figure 3.36 Percent Persons In HOV And Average Mixed-Flow Lanes (Caltrans District Eight, 2005: Peak Hour, Peak Direction)

As would be expected, in nearly every case, the percentage of freeway travelers carried by the HOV lanes is significantly greater than the percentage carried by the average adjacent mixed-flow lane. Exceptions include the under-utilized HOV lanes on SR-71 and the morning peak performance of the I-10 HOV lanes at Haven Avenue observation point and the SR-91 lanes at Jackson. In all other cases, HOV lanes carry more people than the average adjacent mixed-flow lanes in both peak directions. On the average, HOV lanes carry 21.7% of the people in District Eight HOV corridors, while the average adjacent mixed-flow lane carries only 20.2%. Because many of the ridesharers on District Eight freeways were not in HOV lanes when they passed the observation point, the number of people actually sharing rides on District Eight freeways is actually higher than the 21.7% using HOV lanes. When ridesharers in adjacent mixed-flow lanes are added to the equation, a total of 40.7% of travelers using District Eight's freeways during the peak morning and evening hours are sharing rides. For the most part, this relatively high incidence of ridesharing is achieved through carpools, with relatively small contributions from buses.

Measured Violation Rates. Figure 3.37 plots the average violation rates recorded on District Eight's HOV at various observation points during the year 2005. In this case the violation rate is defined as the percentage of vehicles in the lane that fail to meet the minimum occupancy requirement.

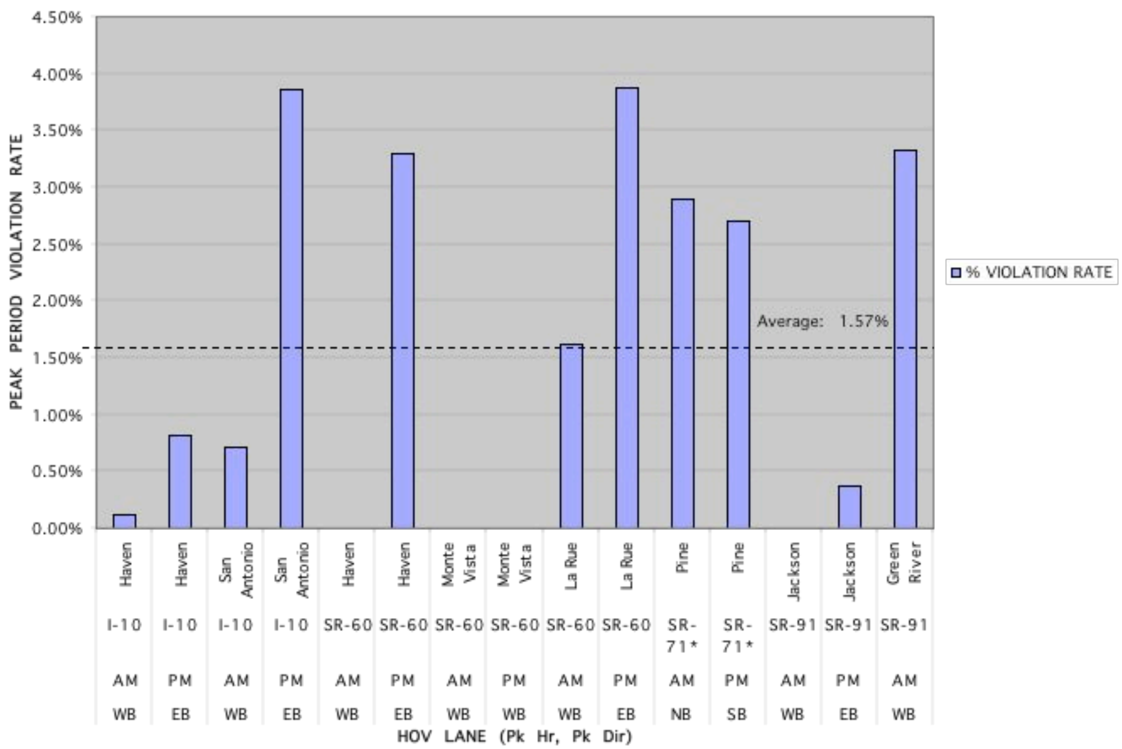


Figure 3.37 Violation Rates Per Lane
(Caltrans District Eight, 2005)

The average violation rate was 1.57%, well below the 10% rate identified in past studies (for example, Billheimer, 1990) as a threshold for concern. None of the District's HOV lanes came close to this threshold during the observation period. The highest violation rates observed on the District's HOV lanes were under 4%.

3.5.6 District Eight Summary

District Eight's HOV lanes average roughly 800 vehicles per lane per hour during the peak commute periods, the minimum acceptable threshold for these operations. While historical data are sketchy, it appears that volumes have been higher in the past. There is little or no data on the time savings available to HOV lane users in San Bernardino and Riverside Counties.

Violation rates average 1.57% throughout the District, well below the 10% level identified as a threshold for concern. Some residents of San Bernardino and Riverside Counties were included in a mailback survey of Orange County freeway users undertaken in 2003, and it appears that public backing for the HOV lanes is strong in these two counties.

While accident rates on I-10 in San Bernardino County increased significantly following the introduction of HOV lanes on that freeway, the implementation of other HOV lanes in the county had no apparent impact on accidents. In the absence of more detailed studies, therefore, the effect of HOV lanes on safety remains somewhat problematic. While carpool lanes on freeways affect congestion and weaving patterns in ways that mixed-flow lanes do not, there is no conclusive evidence that mainline HOV lanes consistently raise or lower accident rates.

3.6 DISTRICT ELEVEN

3.6.1 System Map

CALTRANS District Eleven covers San Diego and Imperial Counties in Southern California. As of December,2002, the area had 28.3 directional miles of HOV lanes reserved for vehicles with two or more (2+) occupants. This HOV network is comprised of a variety of exclusive mainline HOV lanes, including

- Reversible lanes on I-15 that are separated from mixed-flow lanes by a physical barrier and permit entry to Single Occupant Vehicles (SOVs) for a variable fee regulated by the San Diego Association of Governments (SANDAG);
- An HOV toll bypass lane on the Coronado Bridge (State Route 75);
- A northbound HOV lane on the Interstate 5/805 merge;
- A one-mile metered HOV ramp segment on State Route 94; and
- Two-way peak-period HOV lanes on State Route 54.

The network of mainline HOV lanes is supported by a wide range of exclusive facilities designed to encourage ridesharing, including

- An exclusive bus lane on State Route 163;
- Four HOV border crossing gates on Interstate 5; and
- 141 metered ramps with HOV bypass lanes.

A map of existing HOV freeway routes appears in Figure 3.38.

3.6.2 HOV Freeway Inventory

Current Information Appendix D contains an inventory of HOV freeway lanes in District Eleven. The inventory, assembled from data in the most recent (2004) District Eleven HOV Report, lists routes and lane miles by direction, along with occupancy requirements, operating hours, opening dates, and dates and descriptions of subsequent modifications.

Data Availability. Except for a study designed to document the impact of the reversible HOV lanes on I-15 following their implementation in October 1988, very little was done to monitor the performance of HOV lanes in the San Diego area until 1999. While SANDAG published five-year reports on vehicle occupancies in the area, these reports ignored HOV lanes until 1995. Even when occupancy counts were made, moreover, travel times and time savings in the HOV lanes were rarely documented

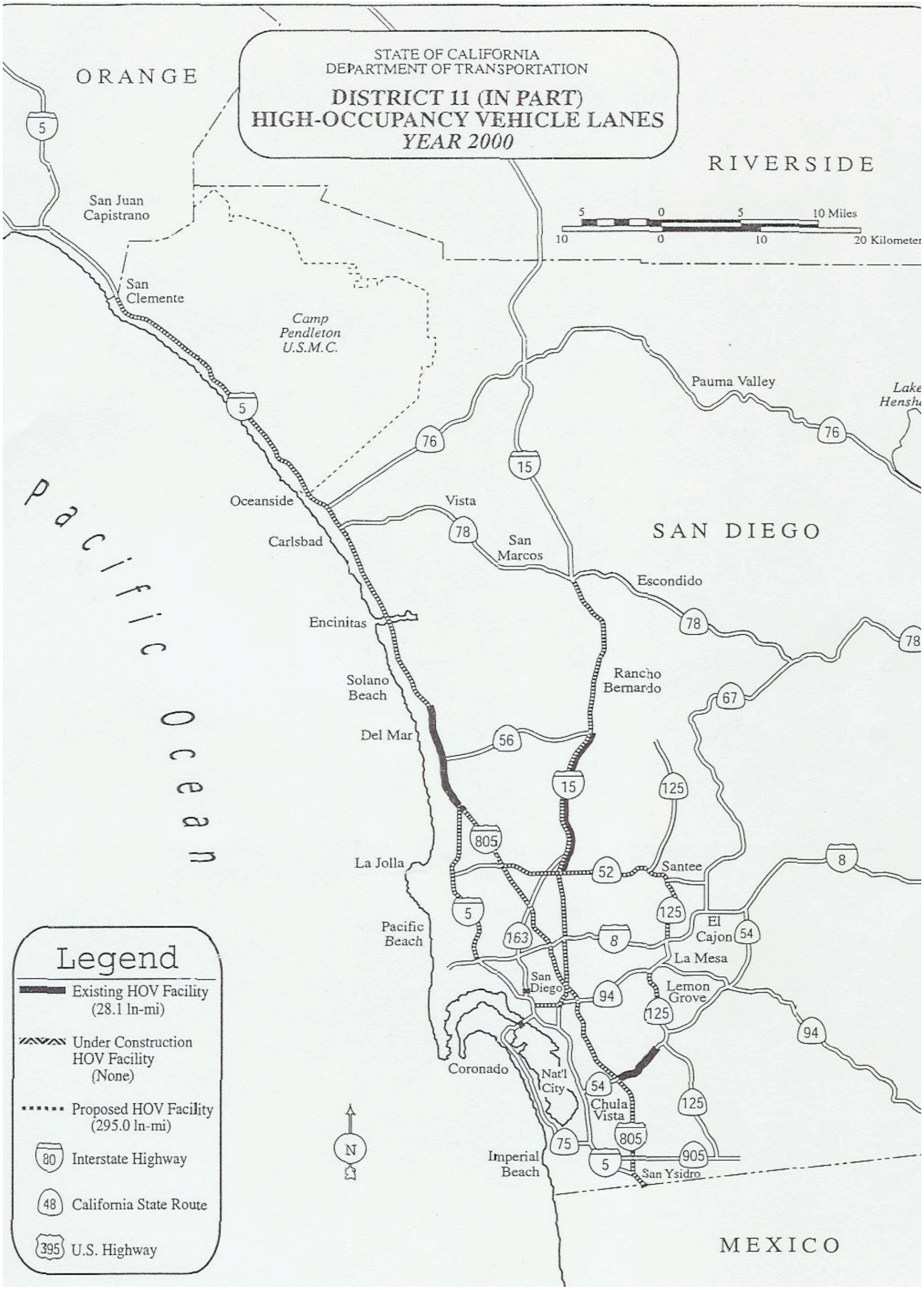


Figure 3.38 Map Of District Eleven HOV Freeway Lanes

In recent years, Caltrans District Eleven has assembled annual reports summarizing HOV operations and documenting the vehicle-and person-carrying performance of HOV lanes and adjacent mainline lanes. Annual Reports for the years 1999 through 2004 were used in preparing this analysis. Unfortunately, these reports have not consistently documented the time savings available to vehicles using the HOV lanes in the San Diego area.

Related Reports. In addition to the annual reports on HOV lanes prepared by District Eleven, several project-specific and system-wide research reports have been prepared covering various HOV lanes in San Diego and the Southern California area. A few of the more prominent are listed below.

TSM Project Violation Rates, Final Report, SYSTAN, Inc. June, 1979

San Diego's HOV Lanes: Making Them Work, CALTRANS District 11, August 1989.

Preliminary Assessment of Effectiveness of Reversible Roadway on Interstate 15 in San Diego , Executive Summary, prepared by San Diego State University, 1989.

HOV Lane Violation Study, SYSTAN, Inc, January 1990.

San Diego Region Vehicle Occupancy and Classification Study (Revised June 2002), SANDAG, June 2002.

Travel Time Analysis of San Diego's Major Traffic Corridors (Task Order 2 Final Report, Prepared for SANDAG by TransCore, April 2003

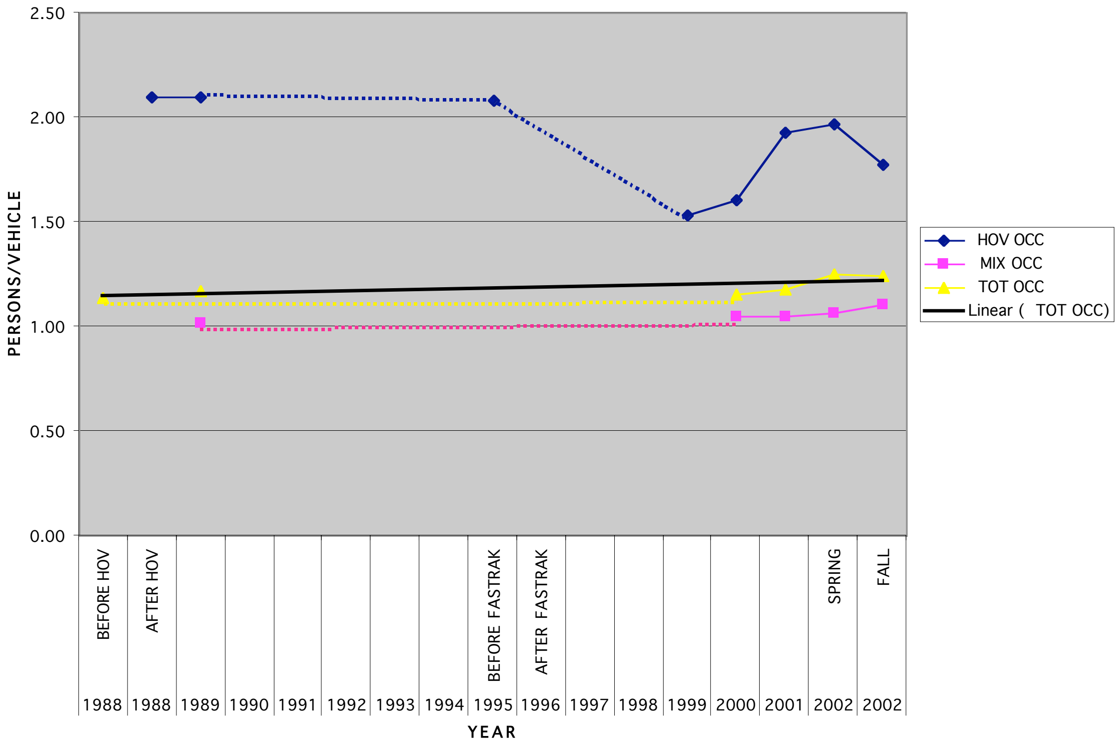
Copies of these reports were assembled and reviewed as background for the analysis of individual HOV projects in District Eleven.

3.6.3 Historical System Performance

The following charts document various aspects of the year-by-year performance of the HOV lanes in CALTRANS District Eleven from their inception to 2002, as reported in the available CALTRANS annual HOV reports.

Average Vehicle Occupancy (AVO): Interstate 15. Because Interstate 15 was the first mainline HOV lane to be opened in the San Diego area, and the first reversible HOV lane in California, its performance was monitored and documented at the time of its immplementation in October 1988.

Figure 3.39 plots AVO over time for I-15, using data available from a variety of reports. The graph shows that AVO increased immediately following the introduction of HOV lanes in1988, rising from 1.14 to 1.17 persons/vehicle as the percentage of carpooling vehicles in the corridor increased from 12.8% to 15.0% during the morning peak. The AVO in the HOV lanes held steady around 2.1 persons/vehicle between 1988 and 1995, and then dropped when the FasTrak program allowed Single Occupant Vehicles to pay for passage through the lanes, falling to 1.5 persons/vehicle in 1999.

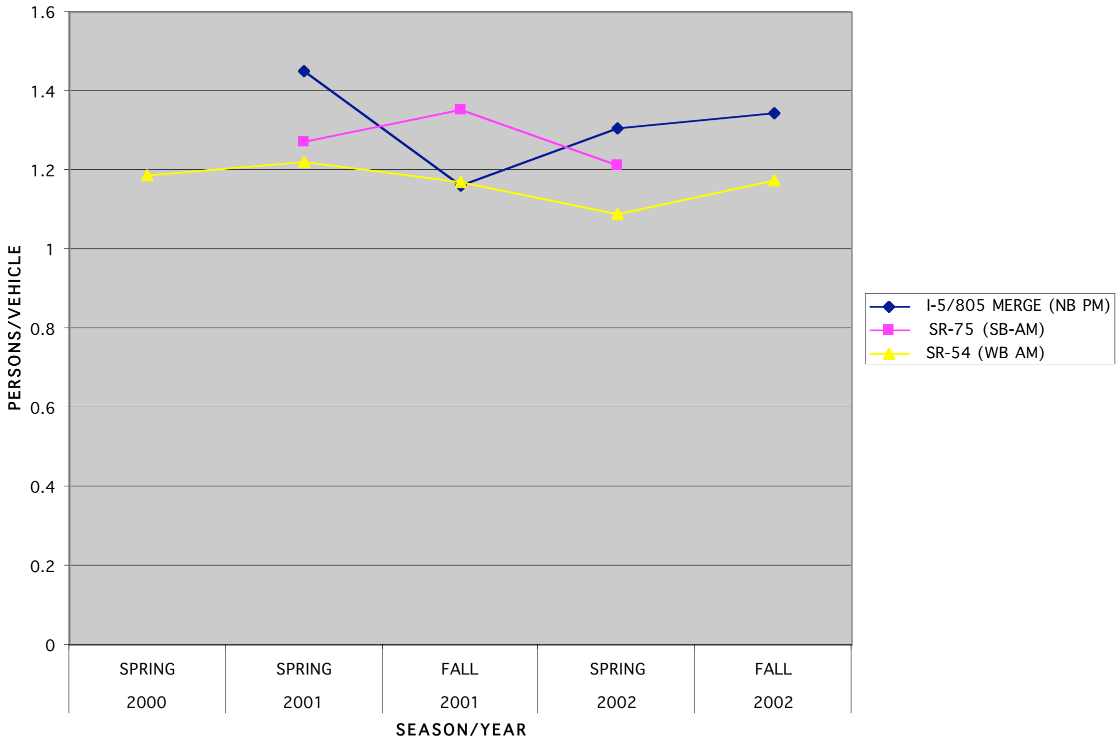


Source: SDSU, 1989; CALTRANS District 11 HOV Reports (1999 – 2002); SANDAG, 2002

Figure 3.39 Average Vehicle Occupancy Over Time. I-15, Southbound AM

Occupancy rates in both the HOV lanes and the adjacent mixed-flow lanes increased after 1999, causing the overall freeway AVO to reach 1.24 persons/vehicle by the fall of 2002. The number of vehicles using the reversible facility during the peak morning hour increased from 602 vehicles/lane just after the 1988 opening to 655 vehicles/lane just prior to the introduction of FasTrak. Following the implementation of FasTrak, the number of vehicles on the reversible lanes jumped markedly, reaching 1129 vehicles/hour in 2002.

AVO: I-5/805 MERGE, SR-75, and SR-54. Figure 3.40 plots AVO rates for the I-5/805 Merge, the SR-75 toll lanes on the Coronado Bridge, and SR-54 in San Diego County between the Spring of 2000 and the Fall of 2002. In the case of all three facilities, AVO decreased slightly over the period of measurement. This is consistent with the behavior of other HOV lanes in Southern California. Because data were not available documenting the AVO on the affected freeways prior to the installation of these HOV lanes, there is no way of knowing whether the existing AVO levels represent an improvement over the "before" case.



Source: CALTRANS District 11 HOV Reports (1999 – 2002)

Figure 3.40 Average Occupancy Rates
I-5/805 Merge, SR-75, And SR-54

Speeds and Travel Times. Relatively little historical data exists documenting speeds and travel times in the HOV lanes and mixed-flow lanes of San Diego County. One exception to this observation involves the reversible lanes on I-15. As the County's first mainline HOV lanes, these were subjected to close scrutiny before and after they opened in October 1988. A preliminary assessment of lane effectiveness undertaken by San Diego State University found that the "opening of the HOV facility brought substantial improvements in travel conditions on main lanes. Average delay during the 3-hour morning peak was reduced from 5.5 min/vehicle in Spring of 1988 to 1.3 min/vehicle in Spring of 1989." Thus the opening of the I-15 reversible lanes eased traffic for both carpoolers and Single Occupant Vehicles, but carpoolers retained a 1.3 minute edge over the vehicles in the mainline lanes.

Historical speed data on the remaining HOV lanes in the study area is either sporadic or non-existent. Anecdotal information suggests that all mainline HOV lanes afforded a free-flowing path to qualified carpoolers immediately after their opening and continue to do so.

3.6.4 Current System Performance

The following charts offer lane-by-lane comparisons of such key performance measures as vehicle volumes, occupancies, and violation rates for the most recent year available, 2002.

Peak-Hour Traffic Volumes: Recent vehicle volumes on District Eleven's HOV lanes are graphed in Figure 3.41, which shows peak-hour volumes in the peak direction of morning and evening flow at several different locations.

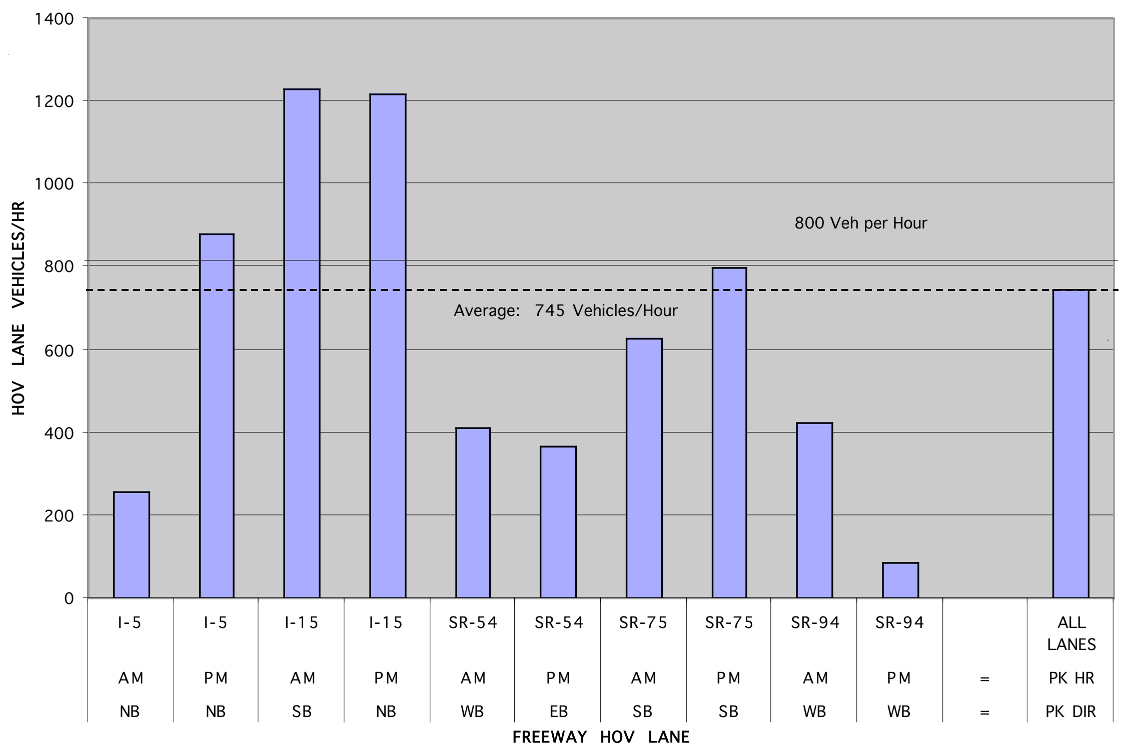


Figure 3.41 Peak Hour Vehicle Volumes
(Caltrans District Eleven, 2002)

The bold horizontal line of Figure 3.41 represents the threshold level of 800 vehicles per hour, which is generally recognized as the minimum operating standard for a mature HOV lane (HOV Systems Manual, NCHRP Report 414). Operations below this level can experience the "empty lane syndrome" at which lanes appear underutilized.

None of District Eleven's HOV lanes currently approach the upper level of 1650 vehicles per hour, at which point free-flow operations can begin to deteriorate, causing the time advantage offered by the HOV lanes to disappear. (Parsons Brinckerhoff, 2002). It's worth noting, however, that the 1200 vehicles per hour per lane performance of the I-15 reversible lanes actually represents a total flow approaching 2400 vehicles per hour.for the two-lane facility.

As indicated in Figure 3.41, the average peak hour flow on all District Eleven HOV lanes was 745 vehicles per hour in 2002. This average is lowered somewhat by the inclusion of measured flows in the off-peak directions on I-15, SR-75, and SR-94.

Person Volumes. Figure 3.42 compares the percentage of freeway person trips carried by District Eleven HOV lanes and adjacent mixed-flow lanes in the peak direction of flow during the peak morning and evening commute hours.

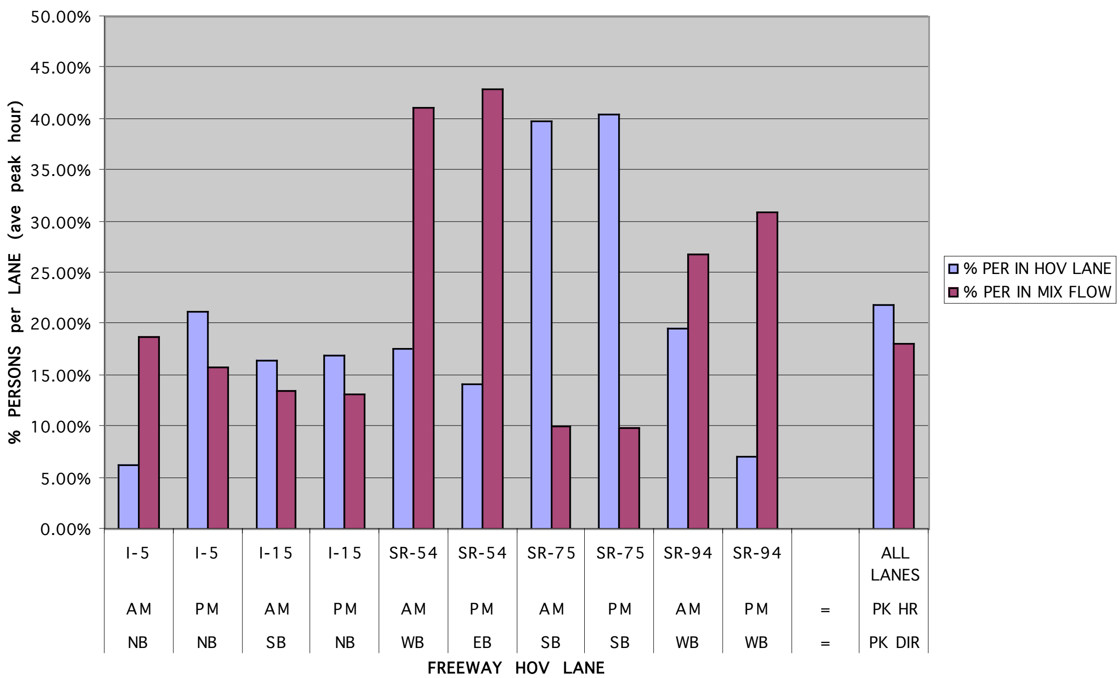


Figure 3.42 Percent Persons In Average HOV And Mixed-Flow Lanes (Caltrans District Eleven, 2002)

On both I-15 and SR-94, the percentage of freeway travelers carried by the average HOV lane is significantly greater than the percentage carried by the average adjacent mixed-flow lane. In the case of SR-54 and SR-94, however, the average mixed-flow lane carries more people than the average HOV lane. On the average, HOV lanes carry 22.9% of the people in District Eleven HOV corridors, while the average adjacent mixed-flow lane carries only 18.1%

Measured Violation Rates. Figure 3.43 plots the average violation rates recorded on District Eleven's HOV lanes at various observation points during the year 2002. In this case the violation rate is defined as the percentage of vehicles in the lane that fail to meet the minimum occupancy requirement.

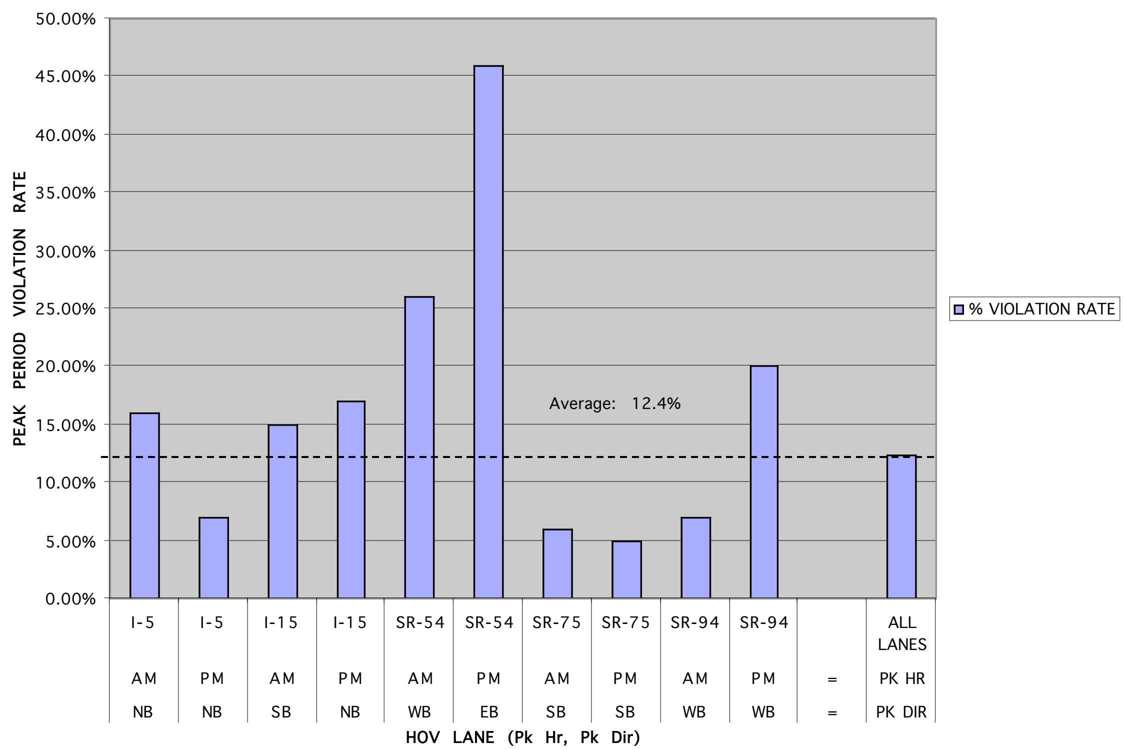


Figure 3.43 Violation Rates Per Lane
(Caltrans District Eleven: 2002)

The average violation rate was 12.4%, well above the 10% rate identified in past studies (for example, Billheimer, 1990) as a threshold for concern. On one freeway, State Route 54, violation rates exceeded 25% during the morning peak and 45% during the evening peak. The violatior rates measured on District Eleven freeways generally exceed those measured in other Districts by a considerable margin. Local CALTRANS personnel speculated that the high rates might be traced to a lack of steady enforcement by the CHP.

Violation rates were not always abnormally high in District Eleven. Early observations made on I-15 shortly after the opening of the reversible lanes recorded rates ranging between 2% and 6% (letter from Joel Haven to John Billheimer, March 22, 1989). It is possible that the introduction of FasTrak operations on the reversible lanes brought on an increased level of violations. Observers can no longer identify violators simply by counting vehicle occupants—Single Occupant Vehicles may qualify if their FasTrak pass is operating. Hence observers must count vehicle occupants <u>and</u> watch the FasTrak indicator at the facility entrance in order to identify violations. Inoperative FasTrak passes or unpaid bills can swell the ranks of the violators. In addition, the fact that driving alone does not automatically mark one as a violator may cause more drivers to use the lanes illegally. Unfortunately, records of violations just before and immediately after the installation of FasTrak operations are not available, so there is no way of documenting the immediate impact of these operations on violation rates.

Another explanation for the high violation rates on I-15 may stem from the position of observers. CALTRANS employees monitoring violations station themselves at the side of the roadway near the entrance to the lanes at the FasTrak ticket booth. In most other CALTRANS jurisdictions, observers record occupancy rates from a vantage point on an overpass above the freeway. It is possible that this higher vantage point provides a better view of the front passenger seat of passing vehicles. This possibility is worth investigating, since CALTRANS personnel report that when CHP officers pursue suspected violators identified from the roadside position, they often find that the supposed violators actually had passengers (i.e., babies or small children) hidden from view. When CHP pursuit results are incorporated in calculating violation rates, these rates reportedly drop significantly (to around 2%, as reported in District Eleven's 2002 HOV Report).

3.6.5 Public Opinion

Driver attitudes, perceptions, and opinions provide an important prism for viewing and evaluating high-occupancy vehicle lanes. In CALTRANS' District Eleven, public attitudes have reflected wide-ranging support of the HOV concept from the initial opening of the reversible lanes on I-15.

The HOV lanes on I-15 were the first mailnine HOV lanes in San Diego County, and they represented the first barrier-separated use of reversible lanes in Southern California. Telephone surveys conducted before and after the implementation of the reversible lanes with randomly selected residents living along the I-15 corridor produced the following results, as reported in San Diego State University's preliminary assessment of the lanes' effectiveness:

- Both (Before and After) Studies recorded an overwhelmingly positive assessment of the facility by users and non-users. About 80% of respondents had "very positive" or "positive" attitudes toward the HOV lanes.

- The carpoolers expressed a high level of satisfaction from HOV lane use. Driving conditions on the HOV facility were consistently assessed as excellent, which is in sharp contrast to the assessment of the conditions on the main lanes of I-15. Drivers perceived a substantial time reduction when using HOV lanes. Often, the perceived time savings were larger than the actual savings.

- Many respondents still highly valued independence of solo driving, yet expressed some disappointment that others do not use the HOV lanes more often.

- The introduction of the HOV facility created a substantial goup of new carpoolers. A small number of previous carpoolers, on the other hand, decided to return to solo driving. One of the reasons for this was their reaction to short-term improvement of travel conditions on the main lanes.

3.6.6 District Eleven Summary

The average HOV lane usage in District Eleven is just under the threshold of 800 vehicles per hour identified as a cause for concern. However, the longest-running mainline facility in the District, the reversible lanes on I-15, have healthy flows of 1200 vehicles/hour during the peak period, or 2400 vehicles/hour for the two-lane facility.

Violation rates average 12.4% throughout the District, slightly above the 10% level identified as a threshold for concern. These rates are much higher than those observed in any other CALTRANS District. Part of the problem on I-15 may stem from the fact that Single Occupant Vehicles with FasTrak passes may use the lanes legally, so that violators are not always easily identified. Public backing for the HOV lanes has been strong from the start, with over 80% of the respondents to telephone surveys made before and after the introduction of the I-15 lanes expressing either "positive" or "very positive" attitudes toward the lanes.

3.7 DISTRICT TWELVE

3.7.1 System Map

CALTRANS District Twelve covers all of Orange County in Southern California. As of December,2004, the area had 240.9 directional miles of HOV lanes reserved for vehicles with two or more (2+) occupants. This network of HOV lanes is supported by a variety of exclusive connectors and feeder lanes, including

- Seven freeway-to-freeway HOV connectors linking I-5 and SR-91, I-5 and SR-55, I-5 and SR-57, I-5 and I-405, SR-57 and SR-91, SR-55 and SR-91, and SR-55 and I-405; and

- Six exclusive drop ramps linking the HOV lanes on I-5 directly with local access roads.

A map of existing HOV freeway routes appears in Figure 3.44.

3.7.2 HOV Freeway Inventory

Current Information Appendix D contains an inventory of HOV freeway lanes in District Twelve. The inventory, assembled from data in the most recent (April 2005) District Twelve HOV Report, lists routes and lane miles by direction, along with occupancy requirements, operating hours, opening dates, and dates and descriptions of subsequent modifications.

Data Availability. In the late seventies and early eighties, when HOV lanes were first introduced in Southern California, each new lane was accompanied by an elaborate process of data collection that documented not only the number of vehicles in the lane, but also time savings, violation rates, and accident impacts. Unfortunately, this extensive process of data collection did not survive into the nineties. For example, vehicle occupancy counts were not regularly made in Orange County between 1995 and 1999. Even when occupancy counts were made, moreover, travel times and time savings in the HOV lanes were rarely documented.

In recent years, Caltrans District Twelve has assembled annual reports summarizing HOV operations and documenting the vehicle-and person-carrying performance of HOV lanes and adjacent mainline lanes. Annual Reports for the years 2000 through 2004 were used in preparing this analysis. While the annual reports have not consistently documented the time savings available to vehicles using Orange County's HOV lanes, current data on travel times in HOV lanes and adjacent mainline lanes are available through the PeMS system.

Related Reports. In addition to the annual reports on HOV lanes prepared by District Twelve, several project-specific and system-wide research reports have been prepared covering various HOV lanes in Orange County and the Southern California area. A few of the more prominent are listed below.

Figure 3.44 Map Of District Twelve HOV Freeway Lanes

TSM Project Violation Rates, Final Report, SYSTAN, Inc. June, 1979

Route 91 Artesia Freeway Operational Report, CALTRANS District 07, December, 1986

Route 55 Newport Costa Mesa Freeway Commuter Lane—18 Month Report, CALTRANS District 7, July 1987.

Route 55 Commuter Study, Orange County Transportation District, February 1988.

An Analysis of Traffic Safety Relative to the Commuter Lane Projects on SR-91 and SR-55 in Orange and Los Angeles Counties, UC Irvine, October 1987.

HOV Lane Violation Study, SYSTAN, Inc, January 1990

Orange County High Occupancy Vehicle Lane Hours of Operation Study, Orange County Transportation Authority, December 1991.

HOV Lane Safety, Cal Poly, September, 1992

Impacts of the SR 91 Value-Priced Express Lanes, Final Evaluation Report, Cal Poly, December 2000.

Orange County High Occupancy Vehicle Lane Operations Policy Study, Parsons Brinckerhoff Quade and Douglas, Inc., August 2002.

A Regional High Occupancy Vehicle System Performance Study: Orange, San Bernardino, and Riverside Counties (Technical Appendix), SYSTAN, Inc, June 2005.

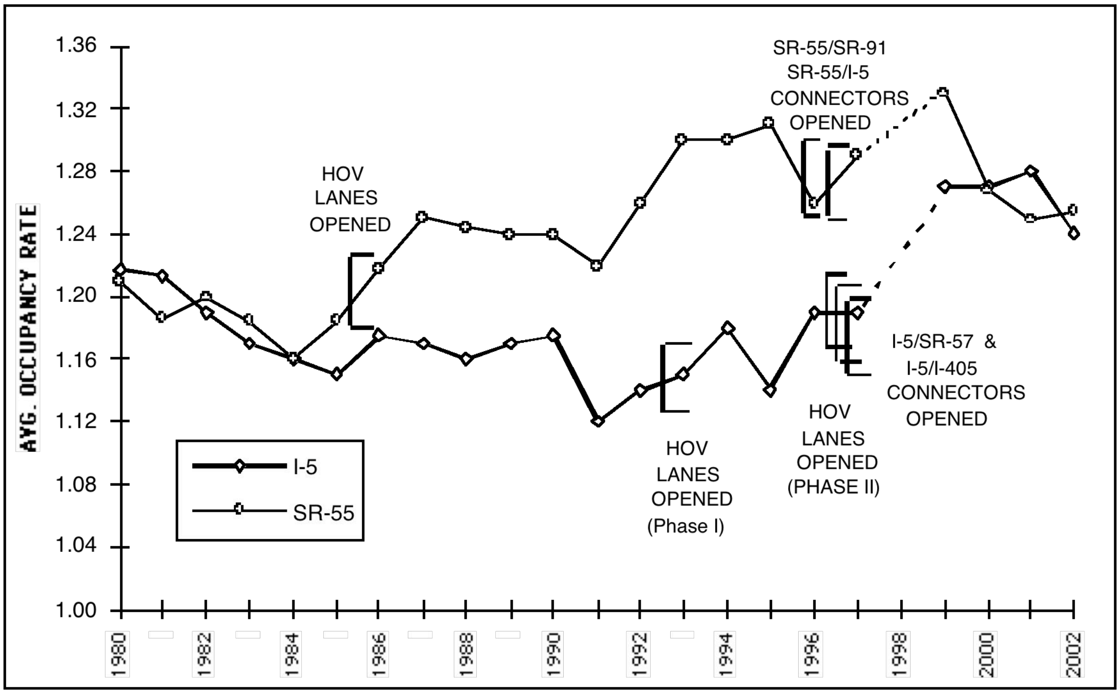
Copies of these reports were assembled and reviewed as background for the analysis of individual HOV projects in District Twelve.

3.7.3 Historical System Performance

The following charts document various aspects of the year-by-year performance of the HOV lanes in CALTRANS District Twelve from their inception to 2003, as reported in the SYSTAN, Inc, Regional HOV Study dated June 2005.

Average Vehicle Occupancy (AVO): SR-55 and I-5. Because State Route 55 was the first HOV lane to be opened in Orange County, its performance was extensively monitored and documented. At the same time, the historical performance of I-5 was documented, partly as a control route against which the effectiveness of SR-55 could be measured.

Figure 3.45 plots AVO over time for the two Orange County freeways, State Route 55 and I-5. The graph shows that AVO tended to increase following the introduction of HOV lanes on both freeways, indicating an increase in ridesharing. In both cases, this increase was found to be statistically significant at the 0.05 level. Whether the increases came from newly formed carpools or carpools which changed routes to take advantage of improved travel times is a question that could only be answered by driver surveys, so that the exact source of the increases are generally unknown.



Source: Klusza, 1987; Sullivan, 2000; CALTRANS District 12 HOV Reports (1999 – 2002); SYSTAN, Inc, 2005.

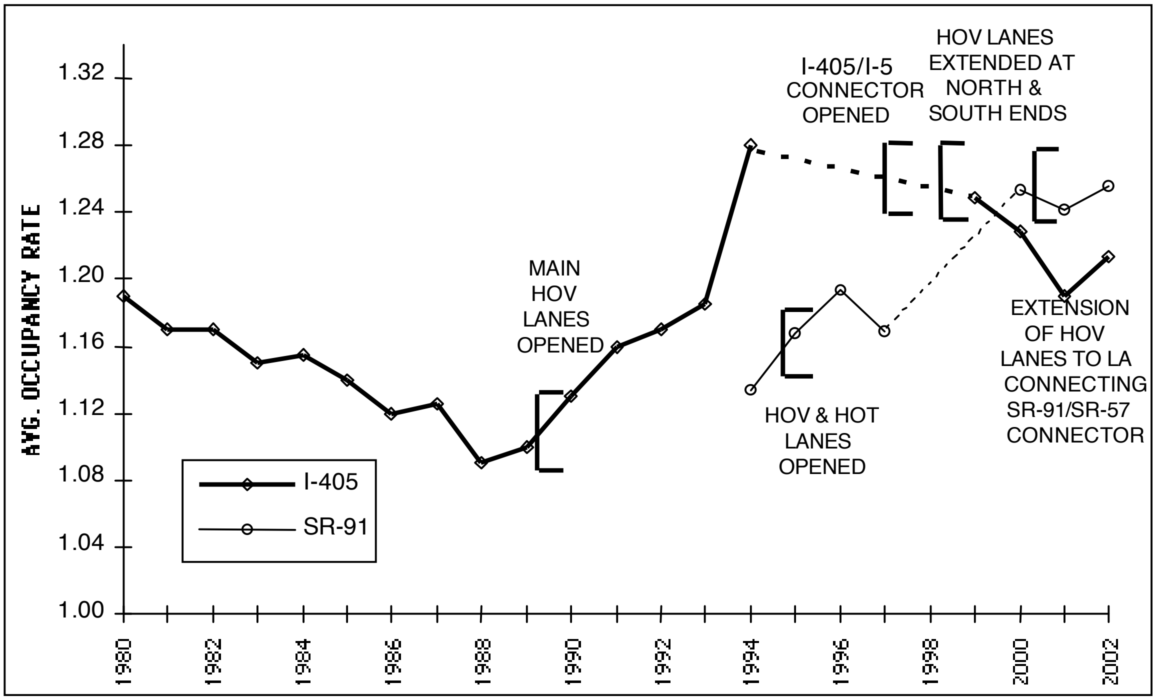
Figure 3.45 Average Vehicle Occupancy Over Time
SR-55 And I-5, Orange County

Average Vehicle Occupancy (AVO): I-405 and SR-91. Figure 3.46 plots AVO rates for I-405 and SR-91 in Orange County before and after the introduction of HOV lanes on those freeways. In the case of I-405, AVO increased steadily following the introduction of nearly twenty miles of HOV lanes in 1989, and rose dramatically in 1994. Recent measurements suggest that AVO has dropped somewhat since its 1999 peak, but still remains significantly higher than its pre-HOV level.

In the case of SR-91, the first segment of HOV lanes in Orange County was opened in August 1995 between SR-57 and SR-55, just prior to the opening of Express Toll lanes from SR-55 to the Riverside County line. (These toll lanes provide discounted toll rates to vehicles with three or more occupants.) In December 2000, the HOV lanes on SR-91 were extended and connected to the existing HOV lanes in Los Angeles County. As part of this project, the SR-91/SR-57 direct HOV-to-HOV connector was also completed.

Figure 3.46 shows that AVO rates on SR-91 increased following the initial implementation of HOV lanes in 1995, dropped slightly in 1997, and were not measured again until 2000, by which time the rate had grown appreciably.

AVO Summary. In every case, the introduction of mainline HOV lanes in Orange County has been followed by an increase in Average Vehicle Occupancy rates, indicating an increase of ridesharing on the freeway. At the current time, there is no way of knowing whether the increases came from newly formed carpools or carpools which changed routes to take advantage of improved travel time.



Source: Klusza, 1987; Sullivan, 2000; CALTRANS District 12 HOV Reports (1999 – 2002); SYSTAN, Inc. 2005

Figure 3.46 Average Occupancy Rate Over Time
Orange County I-405 And SR-91

As time goes on, the question of whether the carpools added to the freeway mix following the introduction of HOV lanes were new or diverted becomes less and less important. If new, they represented an immediate improvement in the overall vehicle occupancy picture. If diverted, they filled space reserved to reward ridesharing behavior and freed up the space they left to relieve the congestion faced by non-carpoolers. Over time, there is evidence that the HOV lanes tend to cause carpools to last longer (See Section 3.7.6), regardless of how they came to use the lanes.

Speeds and Travel Times. Relatively little historical data exists documenting pre-2004 speeds and travel times in the HOV lanes and mixed-flow lanes of Orange County. One exception to this observation involves OR-55. As the County's first HOV lane, it was subjected to intense scrutiny before and after it opened in December 1985. In addition, it was a part of several subsequent studies of HOV lane policies (OCTA, 1991) and enforcement practices (Billheimer, January 1990). Figure 3.47 below tabulates morning peak-hour speeds over the 11.3 mile length of the freeway for three periods: Before lane implementation, one year after lane implementation, and eight years after lane implementation.

Thus the installation of the HOV lanes on State Route 55 afforded an immediate savings of three minutes to mixed-flow drivers during the peak morning hour, and an additional savings of 17.5 minutes to carpoolers with two or more occupants. As time progressed and the number of vehicles in the HOV lane increased, the savings afforded to carpoolers dropped slightly, to 13.3 minutes, still well over one minute per mile.

TIME PERIOD	AVERAGE TRAVEL TIME
BEFORE HOV (Oct. 85)	32.0 minutes
ONE YEAR AFTER HOV (Oct. 86)	
Mixed-Flow Travel Time	29.0 minutes
Savings/Before	3.0 minutes
HOV Travel Time	11.5 minutes
Savings/Before	20.5 minutes
Savings/Mixed-Flow	17.5 minutes
EIGHT YEARS AFTER HOV (1993)	
Mixed-Flow Travel Time	29.6 minutes
Savings/Before	2.4 minutes
HOV Travel Time	16.3 minutes
Savings/Before	15.7 minutes
Savings/Mixed-Flow	13.3 minutes

Source: Dowling Associates, September 1995

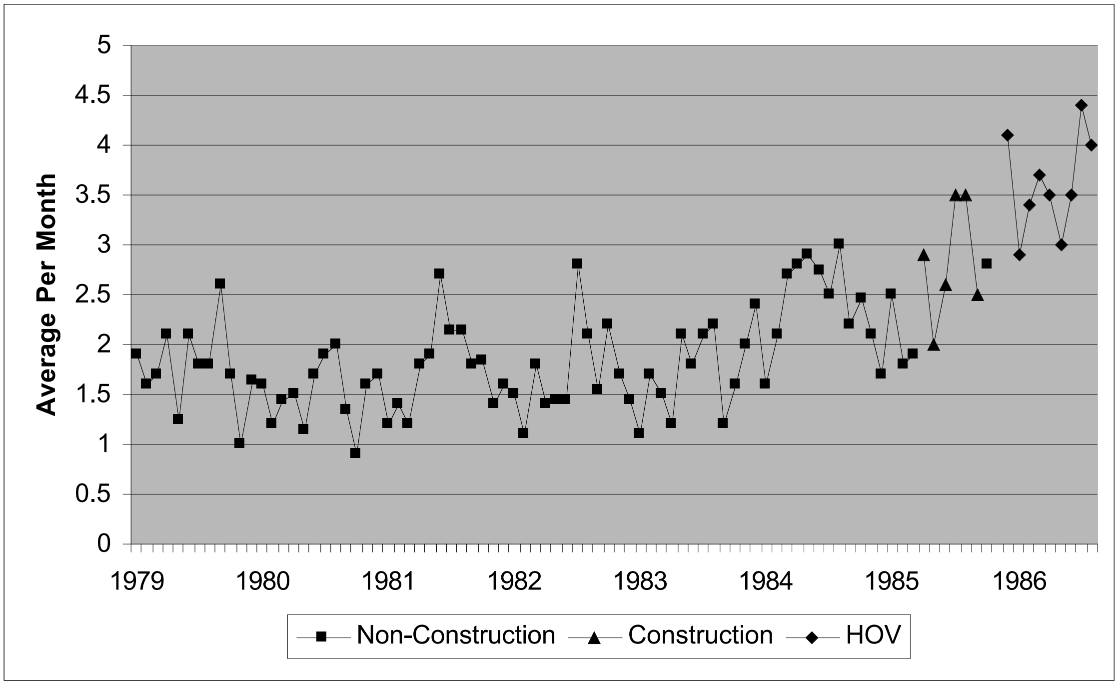
Figure 3.47 Travel Time Savings, SR-55 Southbound
7:00 AM – 8 AM, 11.3 Miles

Historical speed data on the remaining HOV lanes in the study area is either sporadic or non-existent. Anecdotal information suggests that all mainline HOV lanes offered a free-flowing path to qualified carpoolers immediately after they opened. Information on current speed differentials, delays, and time savings may be found in Section 3.7.5.

3.7.4 HOV Lane Safety

The following subsections summarize the historical accident data associated with the introduction of mainline HOV lanes and freeway-to-freeway connectors in Orange County, as originally reported in the regional system performance study sponsored by SCAG (SYSTAN, 2005).

State Route 55. An apparent increase in accident levels following the implementation of HOV lanes on Orange County's State Route 55 triggered a detailed investigation by the University of California in Irvine. The investigation assembled time series records of accident levels before construction began on the freeway, during construction, and immediately following the implementation of HOV lanes. Time series data for dry weekdays appears in Figure 3.48.



Source: U.C. Irvine Institute for Transportation Studies, October 1987

Figure 3.48 SR-55 Freeway Accident History

Their analysis was hampered by the lack of consistent volume data on the freeway segment. After examining accident locations and congestion patterns and applying a time series regression to account for the increase in accidents prior to the introduction of HOV lanes, the investigators concluded...

> ..that the HOV lane on SR-55 has contributed to an increase in accidents on that route of no greater than 2 percent over and above the level that would be expected from mixed-flow operation of the lane. That is, there are up to approximately 2 percent more accidents on SR-55 resulting from HOV operation of the added lane, as opposed to mixed-flow operation. This 2 percent estimate is an upper bound. It is entirely possible that there are no additional accidents due to the HOV lane, but it is impossible to confirm the no-effect hypothesis with existing data." (U.C. Irvine ITS, October 1987)

I-405. The HOV facility on I-405 in Orange County was implemented in five stages starting in January 1989 and ending in May 1990. Investigators at Cal Poly (Sullivan, et al., September 1992) assembled accident data over the 24-mile stretch of freeway for the one-year period between July 1990 and June 1991 and compared this with the accident data on a control segment of I-405 in Los Angeles County which had been widened in early 1984 without incorporating an HOV lane (at that time). A comparison of accident rates per million vehicle miles on the two freeway segments by time of day appears below in Figure 3.49.

SECTION	DIRECTION	TIME OF DAY					
		AM PEAK	MID-DAY	PM PEAK	NIGHT TIME	WEEKEND PEAK	WEEKEND DAY
ORA 405 HOV	NB	1.041	0.534	0.862	0.633	0.212	0.391
	SB	0.940	0.402	0.818	0.467	0.233	0.278
LA 405 CNTRL	NB	0.983	0.917	1.560	1.919	0.873	0.830
	SB	0.416	1.218	1.740	2.070	1.268	0.817

Source: Sullivan, et al., September 1992.

Figure 3.49 Accident Rates Per Million Vehicle-Miles
I-405 In Orange County Vs I-405 In LA County

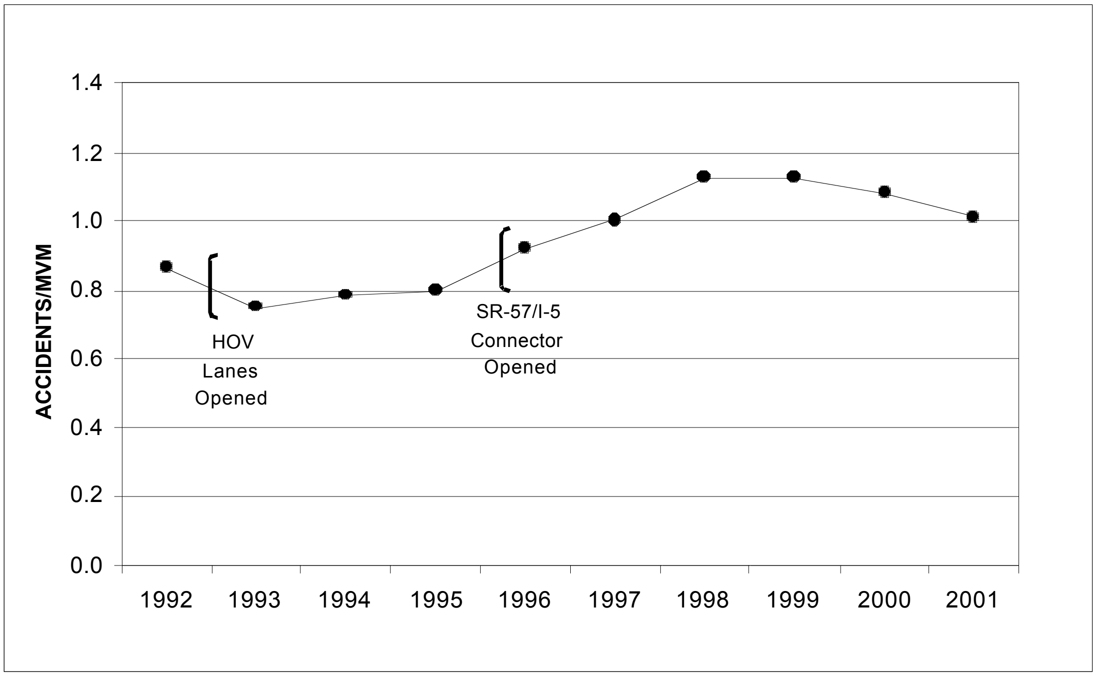
In general, accident rates on I-405 in Orange County tended to be lower than the rates on the control freeway, I-405 in Los Angeles County, except for the a.m. peak period in the north-bound and south-bound directions. The Cal Poly investigators also reviewed the spatial distribution of accidents, the relationship of accidents to congestion, types of collisions, and the accident reports themselves to conclude that "...accidents (on I-405 in Orange County) are not affected by the presence of the HOV facility."

State Route 91 HOT Lanes. In 1989, state legislation (AB-680) was approved allowing CALTRANS to enter into agreements with the California Private Transportation Company (CPTC) to construct four Express Toll Lanes (HOT Lanes) in the median of SR-91 from SR-55 to the Riverside County Lines. This facility was opened to traffic in December 1995 and provided carpools with three or more people free or discounted toll rates. Because the concept of HOT Lanes was new in California, the lanes on SR-91 were subjected to close scrutiny. Statistics on throughput, traffic trends, corridor travel behavior, accidents, and emissions were closely monitored and analyzed in a five-year study undertaken by Cal Poly and sponsored by CALTRANS and the U.S. Department of Transportation (Sullivan, December 2000).

Year-by-year accident data for the Orange County HOT lanes showed a reduction in fatal and injury, and total accidents immediately after the introduction of the toll lanes. The analysts cautioned, however, that the observation period prior to the opening included the construction period, which typically experiences unrepresentative behavior patterns. Fatal and injury accident rates returned to pre-project levels after 1996. All in all, the Cal Poly report concluded that the SR-91 HOT lanes were "...operating at an acceptable level of safety."

SR-57. The SR-57 HOV lanes in Orange County opened in November 1992, and originally extended roughly 10 miles between the "Orange Crush" intersection of SR-57, SR-22, and I-5 in Orange to Lambert Road. In August 1997, the HOV lane was extended from Lambert Road to SR-60 in Los Angeles County, lengthening the Orange County portion of the HOV lane to 12 miles. The year before the northern end of the lane was extended, an HOV-to-HOV connector was installed at the heart of the Orange Crush linking the I-5 and SR-57 HOV lanes.

Figure 3.50 tracks total accidents per million vehicle miles on SR-57 for the years 1992 to 2001. The figure shows that the accident rate dropped immediately following the initial HOV lane installation, then rose significantly in 1996 and 1997 after the HOV-to-HOV connector was opened. A key reason for this increase was the backup caused when the two well-utilized HOV lanes on I-5 and SR-55 were fed directly into the single lane on I-5. Additional discussion of the accident impacts of Orange County's HOV-to-HOV connectors may be found later in this subsection.

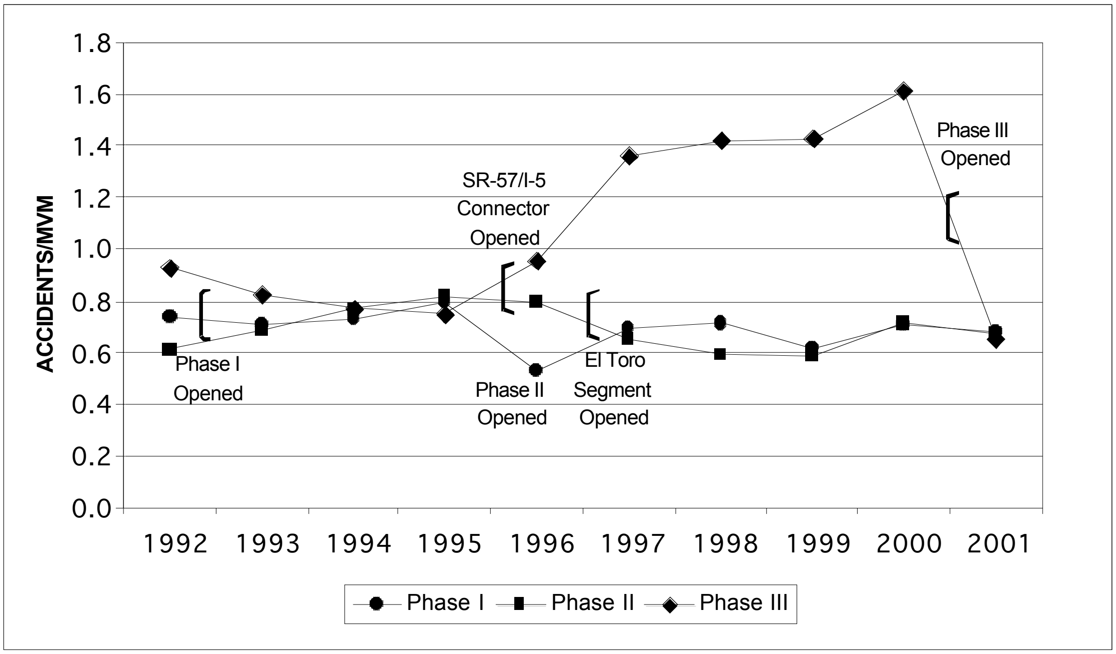


Source: TASAS; SYSTAN, 2005.

Figure 3.50 Accidents Per Million Vehicle Miles
State Route 57, SR-22, I-5 Interchange To Lambert Road

<u>Interstate 5</u>. The HOV addition to Interstate 5 in Orange County was completed in phases, starting in October 1992 with a 7.5 mile stretch between Alton Parkway and Newport Avenue in the center of the county. The next major addition came in May 1996, with the extension from Newport Avenue north to the Santa Ana River and the opening of the I-5/SR-57 HOV-to-HOV connectors. Between July 1996 and October 1997, the I-5 HOV lanes were extended south to meet State Route One near the ocean and San Juan Capistrano. Finally, between September 2000 and January 2001, the lanes were extended northward from Orange County to Beach Boulevard. The HOV lanes currently cover forty directional miles (79.4 lane miles) stretching nearly the length of Orange County.

Figure 3.51 plots accidents per million vehicle miles for the ten years between 1992 and 2001 on three segments of I-5 in Orange County. On the first, central, segment between Alton Parkway and Newport Avenue, accidents dropped slightly following implementation, rose slightly, then generally remained lower than pre-HOV levels throughout the ten-year period. Over that period, post-HOV rates were 6.7% lower than pre-HOV rates.



Phase I: Alton Parkway to Newport Avenue
Phase II: Route 1 to Alton Parkway and Newport Avenue to Santa Ana River
Phase III: Santa Ana River to Beach Boulevard

Source: TASAS; SYSTAN 2005.

Figure 3.51 Accidents Per Million Vehicle Miles
I-5 Segments In Orange County

In the case of Phase II, which extends from the Santa Ana River south to Route One (excluding the 7.5 mile stretch of Phase I), accidents rose slightly prior to the opening of the first segment of the construction phase in 1996, then dropped steadily through 1999. In general, post-HOV levels were 15% lower than pre-HOV levels over the ten-year period.

The accident history along Phase III, which extends from the Santa Ana River just north of the Orange Crush northward to Beach Boulevard, differs from that of the other two construction phases. Beginning in 1996, accident rates along the stretch of freeway shot up significantly, increasing by 48% over pre-1996 rates.

There are at least two possible reasons for this increase. (1) The installation of the I-5/SR-57 connector in 1996 caused back-ups in the HOV lane on I-5 and merging problems as carpoolers bailed out of the HOV lanes to avoid the Orange Crush. (2) The increase could also reflect construction activity prior to the opening of Phase III between September 2000 and January 2001. The fact that accident levels dropped dramatically in 2001 following the opening of the final stretch of HOV lanes on I-5, falling to its lowest level over the ten-year period, suggests that the congestion accompanying construction activity may have accounted for the bulk of the observed increase.

<u>Mainline Lanes Summary</u>. In most instances, the installation of mainline HOV lanes in Orange County had no discernible impact on accident rates over the freeway segments involved. This is not necessarily a clean bill of health for these lanes, since they were generally formed by adding a lane to the freeways, thereby reducing overall congestion and, presumably, the likelihood of accidents.

In a few cases, such as SR-55 and the northernmost segment of I-5, the installation of HOV lanes was accompanied by an increase in accident rates. The exact cause of these accidents is difficult to determine in retrospect. In the case of I-5, for example, the increase may reflect either the backup in the HOV lanes caused by overloading the "Orange Crush," where I-5, SR-57, and SR-22 meet in Orange, California, or the omnipresence of highway construction in Southern California, which often occurred in the vicinity of newly opened HOV lanes.

In the absence of definitive data to the contrary, several investigators (Sullivan, et al., September 1992; LACMTA, November 2002; and SYSTAN, June 2005) have concluded that

> "...no distinct trends or patterns were identified that can be attributed directly to facilities with carpool lanes versus facilities without carpool lanes."

In general, these studies conclude that "...accident rates on the facilities with carpool lanes are influenced by traffic congestion, vehicular mix, and roadway conditions in the same way that these factors affected facilities without carpool lanes" (LACMTA, November 2002). While this statement is intuitively obvious, it ignores the fact that carpool lanes affect congestion and weaving patterns in ways that facilities with no carpool lanes do not.

Freeway-to-Freeway Connectors. The installation of freeway-to-freeway connectors linking Orange County's HOV lanes has almost universally resulted in a decrease in accident rates in the vicinity of the freeway intersection. Figure 3.52 summarizes accident rates within two miles of the key freeway intersections in Orange County before and after the installation of six of the county's freeway-to-freeway connectors.

Five of the six intersections showed a decline in accident rates following the installation of connectors and the imputed reduction in accidents on these intersections ranged from a savings of 19 accidents per year on the SR-57/I-5 connector to 124 accidents/year on the SR-91/I-5 connector. In the case of the one intersection in Figure 3.52 that shows an increase in accident rates, the I-5/SR-55 connector, the increase can be attributed to construction on SR-55 south of the interchange.

FWY TO FWY CONNECTOR	DATE OPENED	ACC/MVM BEFORE	ACC/MVM AFTER	DIFF (%)
SR-91/SR-57	FEB '00	1.21	1.13	-6.8%
I-5/SR-57	MAY '96	1.34	1.27	-4.9%
I-5/SR-55	MAR '96	1.05	1.14	8.9%
I-5/SR-405	JULY '96	0.93	0.62	-33.8%
SR-91/SR-55	DEC '95	1.00	0.85	-15.0%
I-5/SR-91	JAN '01	1.35	0.96	-28.8%

Figure 3.52 Accident Rates Before And After The Opening Of HOV-To-HOV Connectors In Caltrans District Twelve

Thus the recent SCAG study (SYSTAN 2005) concluded that the installation of direct HOV-to-HOV connectors almost universally reduced accident rates in the vicinity of affected intersections.

3.7.5 Current System Performance

The following charts offer lane-by-lane comparisons of such key performance measures as vehicle volumes, occupancies, travel time savings, and violation rates for the most recent year available, 2003.

Peak-hour Traffic Volumes. Recent vehicle volumes on District Twelve's HOV lanes are graphed in Figure 3.53, which shows peak-hour volumes in the peak direction of morning and evening flow at several different locations.

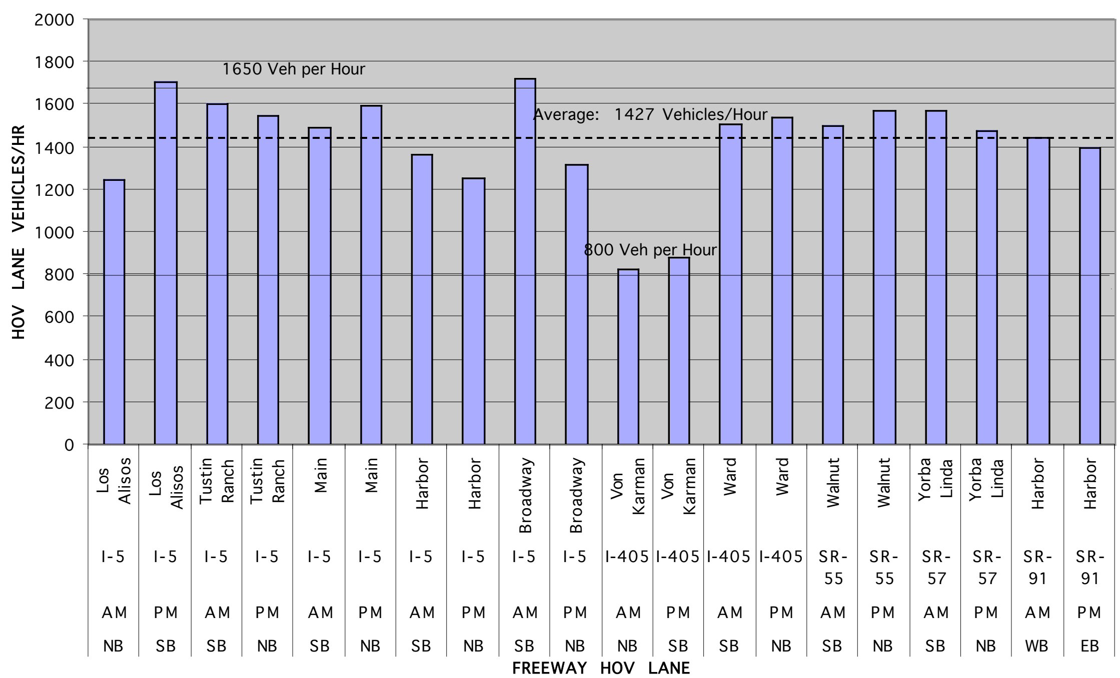


Figure 3.53 Peak Hour Vehicle Volumes, 2004

The bold horizontal lines of Figure 3.53 represent two generally recognized measures of performance for HOV lanes.

(3) The lower level of 800 vehicles per hour, which is generally recognized as the minimum operating standard for a mature HOV lane (HOV Systems Manual,

NCHRP Report 414). Operations below this level can experience the “empty lane syndrome” at which lanes appear underutilized.

(4) The upper level of 1650 vehicles per hour, at which point free-flow operations can begin to deteriorate, causing the time advantage offered by the HOV lanes to disappear. (Parsons Brinckerhoff, 2002)

As indicated in Figure 3.53, the HOV freeway lanes in District Twelve exceeded the minimum operating standard of 800 vehicles per hour at every observation point. The average peak hour flow on all District Twelve HOV lanes was 1427 vehicles per hour in 2004, so there is little danger that the district’s HOV lanes will fall victim to the “empty lane syndrome.” In fact, the HOV lanes on I-5 exceeded the upper limit of 1650 vehicles per hour at two locations: The southbound observation point at Broadway during the morning commute, and the southbound observation point at Los Alisos during the evening commute.

Person Volumes. Figure 3.54 compares the percentage of freeway person trips carried by District Twelve HOV lanes and adjacent mixed-flow lanes in the peak direction of flow during the peak morning and evening commute hours.

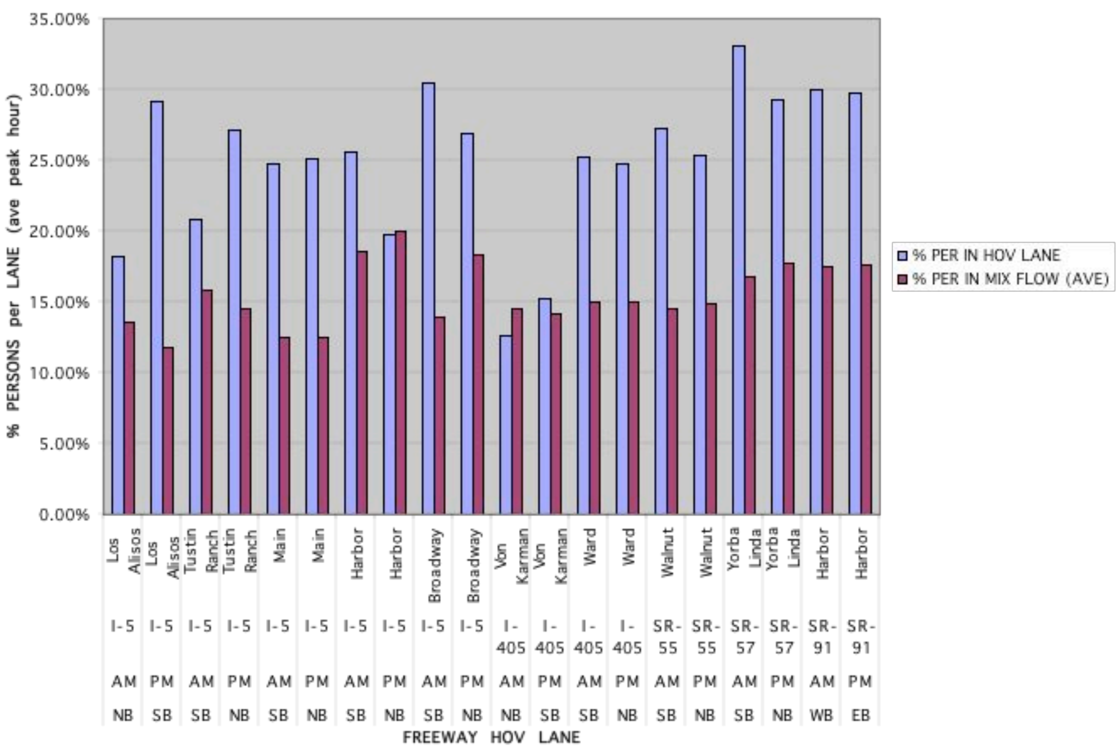


Figure 3.54 Percent Persons In HOV And Average Mixed-Flow Lanes
(Caltrans District Twelve, 2004: Peak Hour, Peak Direction)

As would be expected, in nearly every case, the percentage of freeway travelers carried by the HOV lanes is significantly greater than the percentage carried by the average adjacent mixed-flow lane.

The single exception is the morning peak performance of the HOV lanes on I-405 at the Von Karman observation point. In all other cases, HOV lanes carry more people than the average adjacent mixed-flow lanes in both peak directions. On the average, HOV lanes carry 25.0% of the people in District Seven HOV corridors, while the average adjacent mixed-flow lane carries only 15.3%. Because many of the ridesharers on District Twelve freeways were not in HOV lanes when they passed the observation point, the number of people actually sharing rides on District Twelve freeways is actually higher than the 25.0% using HOV lanes. When ridesharers in adjacent mixed-flow lanes are added to the equation, a total of 36.4% of travelers using District Twelve's freeways during the peak morning and evening hours are sharing rides. For the most part, this relatively high incidence of ridesharing is achieved through carpools, with relatively small contributions from buses.

<u>Travel Time Savings.</u> Figure 3.55 graphs the time savings available on each leg of District Twelve's HOV freeway network. Time savings were calculated by comparing the delays recorded in the PeMS system by vehicles traveling the entire length of individual HOV lanes with the corresponding delays recorded by vehicles in adjacent mixed-flow lanes. In one case, I-405, travel time statistics were available from both floating car runs and the PeMS network.

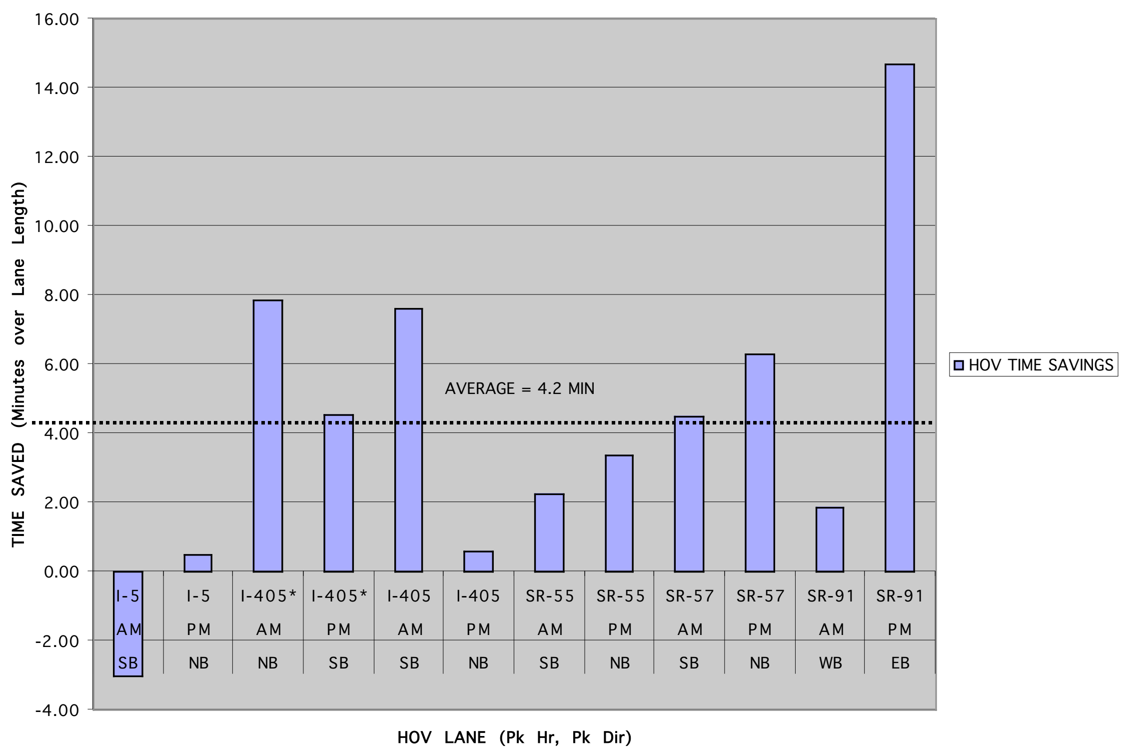


Figure 3.55 HOV Lane Time Savings
(Caltrans District Twelve: Peak Hour, Peak Direction)

Note: The data for I-405 reflect savings recorded by CALTRANS floating car runs. In all other instances, time savings were computed from PeMS records.

The HOV Systems Manual (NCHRP Report 414) suggests that a savings goal of five minutes per trip, and/or one minute per lane mile, be used to gauge the success of HOV lane operations. As shown in

Figure 3.55, the only HOV lanes in District Twelve that do not meet the five-minute criterion in at least one direction are I-5 and SR-55. In the case of I-5 during the morning peak, mixed-flow lanes actually out-perform the adjacent HOV lane by a considerable margin. This reflects the impact of the "Orange Crush", the name given by locals to the intersection of I-5, SR-57, and SR-22, where the HOV-to-HOV connector from SR-57 feeds the southbound I-5 HOV lane directly, causing a backup in both HOV lanes. As a result of this backup, HOV lane users actually experience an average loss of three minutes relative to drivers in the mixed-flow lanes.

Even with the loss of time experienced by HOV lane users passing through the "Orange Crush," the average time savings for all District Twelve HOV lanes recorded in 2004 was 4.2 minutes (0.36 minutes per mile), just slightly below the five-minute success threshold defined in the HOV Systems Manual.

<u>Measured Violation Rates</u>. Figure 3.56 plots the average violation rates recorded on District Twelve's HOV at various observation points during the year 2004. In this case the violation rate is defined as the percentage of vehicles in the lane that fail to meet the minimum occupancy requirement.

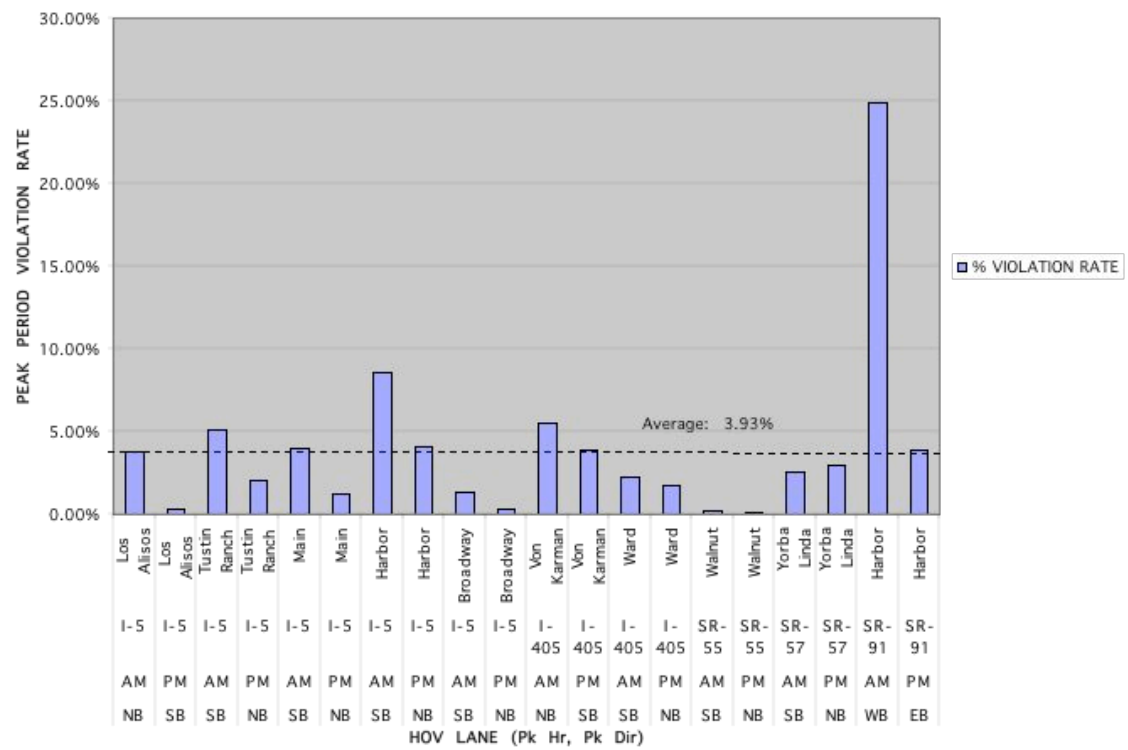


Figure 3.56 Violation Rates Per Lane
(Caltrans District Twelve, 2004)

The average violation rate was 3.9%, well below the 10% rate identified in past studies (for example, Billheimer, 1990) as a threshold for concern. Only one set of District Twelve HOV lanes, the westbound lanes on SR-91, exceeded this threshold during the observation period.

Driver Perceptions of Violations. Participants in a series of three 2003 focus groups (SYSTAN, 2005) were asked to comment on the illegal use of Orange County's HOV lanes by solo drivers. In general, these participants did not feel that the illegal use of carpool lanes by solo drivers presented a serious problem. All three groups estimated that occupancy violators constituted less than ten percent of the vehicles in the lanes. Participants were far more concerned about drivers who entered and left the lane illegally between designated entry and exit points, since these drivers constituted a potential safety hazard.

3.7.6 Public Opinion

Introduction. Driver attitudes, perceptions, and opinions provide an important prism for viewing and evaluating high-occupancy vehicle lanes. In CALTRANS' Southern California' Districts, public attitudes have undergone a remarkable change, from heated opposition to HOV lanes in the wake of the disastrous experiment on the Santa Monica Freeway to wide-ranging support of the current region-wide network

It is instructive to trace the attitudes of District Twelve drivers toward HOV lanes as revealed in focus groups and surveys conducted over the period of nearly twenty years since preferential lanes were first introduced on State Route 55 in Orange County. These were the first freeway HOV lanes in the County, and they represented the first extensive HOV project in Southern California since the failure of the Santa Monica Diamond Lanes in 1976. Driver surveys were conducted for a variety of purposes over this period, but the different surveys had enough in common to provide a glimpse of driver attitudes toward such issues as perceived time savings, carpool formation, violation rates, and general support for the HOV concept. Some of the key surveys of District Twelve drivers that have focused on HOV issues are listed below in chronological order.

YEAR	REPORT	SPONSOR	FIRM	SURVEY TYPE	TARGET
1981	TSM Project Violation Rates	CHP, CALTRANS	SYSTAN	Focus Groups, Mailback	CP+Solo
1988	Route 55 Commuter Study	OCTA	OCTA	Mailback	CP+Solo
1990	HOV Lane Violation Rates	CALTRANS	SYSTAN	Focus Groups, Mailback	CP+Solo
2003	Orange County Driver Survey	SCAG	SYSTAN	Focus Groups, Mailback,	CP+Solo

The most recent survey of Orange County Drivers was undertaken by SYSTAN, Inc. in 2003 as part of an evaluation of HOV lanes in Orange, San Bernardino, and Riverside Counties undertaken for the Southern California Association of Governments. Surveys were mailed to 5,945 drivers observed using I-405, SR-55, and the SR-55/I-5 freeway-to-freeway connector. Surveys were sent to both carpoolers and solo drivers, and the mailing produced 764 completed surveys (12.9% of the total mailed). The surveys captured information on trip purpose, origins and destinations, travel times, ridesharing habits and propensities, demographic characteristics, and general attitudes toward Southern California's preferential lanes.

Drivers responding to the survey were given the opportunity of volunteering for three focus group discussions held at the office of the Orange County Transportation Authority. The three focus group discussions were designed to provide a "driver's-eye-view" of the commute in Orange County and probe attitudes towards HOV lanes and policy issues in some depth. Except as otherwise noted, the results cited below reflect the findings of the 2003 mailback surveys and focus groups. (Billheimer and McNally, October 2003).

HOV Lane Support. Drivers responding to the 2003 SCAG survey of Orange County drivers were asked to classify their support or opposition to having bus/carpool lanes on Southern California freeways. Answers showed strong support for carpool lanes, with 75.8% of all drivers expressing either support (32.7%) or strong support (43.1%) and only 11.7% expressing opposition. The remaining 12.6% of respondents were neutral. These results are summarized in the graph of Figure 3.57.

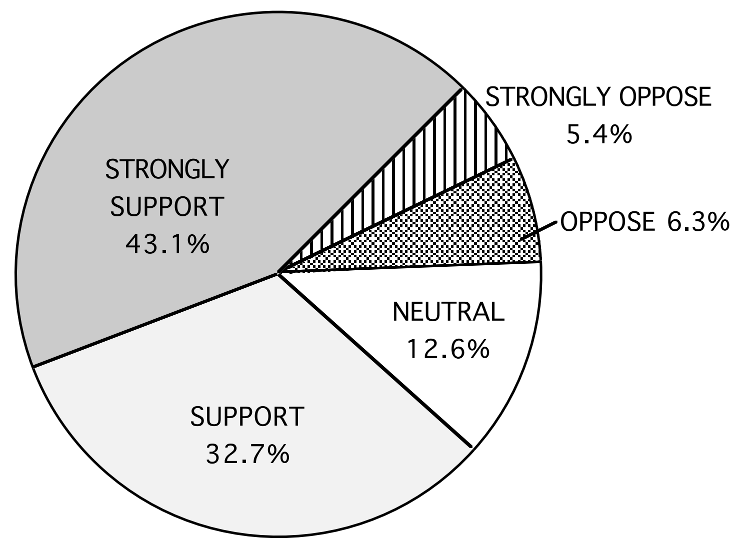


Figure 3.57 Support For Orange County HOV Lanes
(Answers to: "Do you support or oppose having bus/carpool lanes in Southern California?")

Perceived and Actual Time Savings. A common thread in all survey results, from the earliest to the most recent, is the agreement that HOV lanes save time for carpoolers and the tendency of both carpoolers and non-carpoolers to overestimate that savings. These findings were confirmed in the 2003 SYSTAN survey, which showed that both carpoolers and solo drivers tended to overestimate the amount of time they could save by using the bus/carpool lanes along their morning route. The average HOV lane savings estimated by carpoolers and solo drivers on the three routes covered by the survey are plotted in Figure 3.58 and compared with the most recent estimates of time savings measured by speed runs or SCAG's PeMS data base.

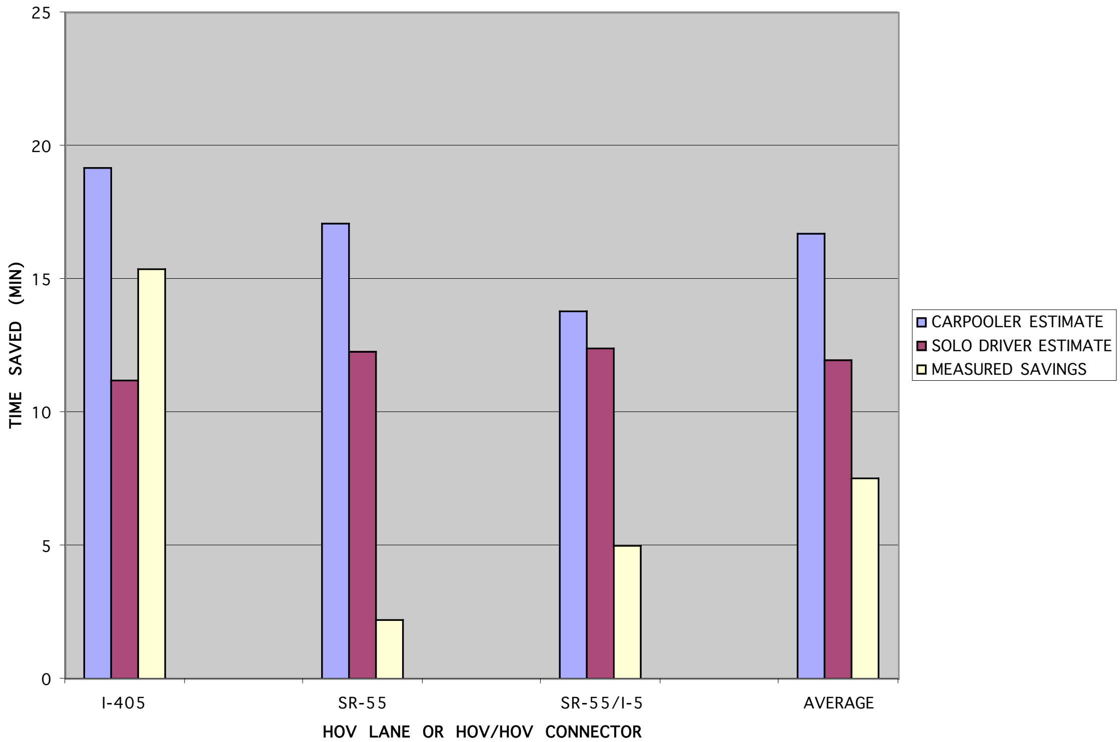


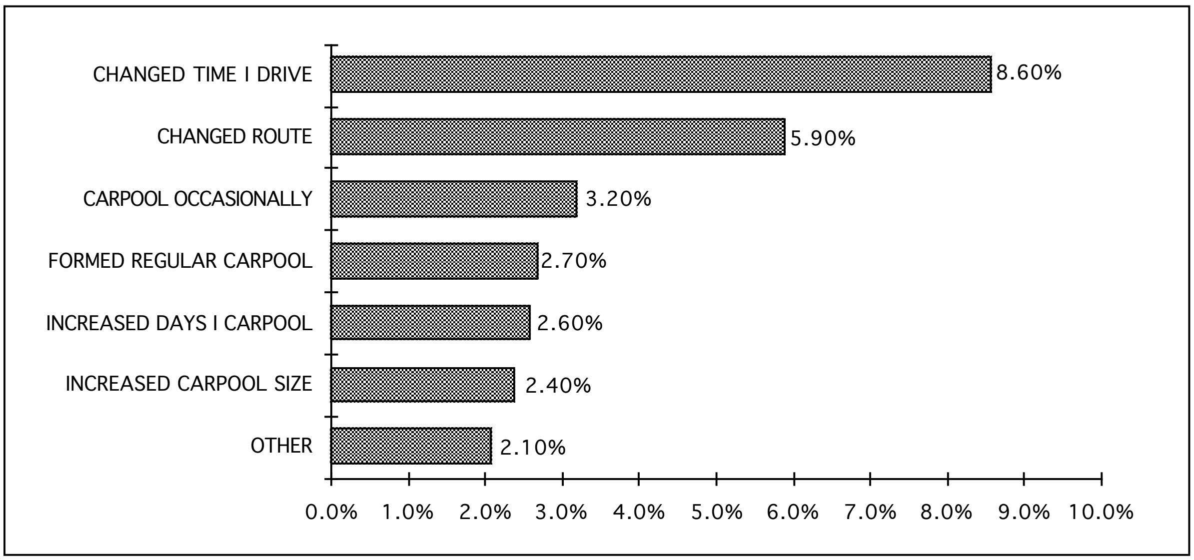
Figure 3.58 Estimated And Actual HOV Lane Time Savings
Orange County HOV Lanes

During the peak morning commute hour (8:00 to 8:59 a.m.), CALTRANS speed runs showed a savings of 15.4 minutes for drivers traveling the length of the I-405 carpool lanes. Carpoolers using I-405 estimated their savings at 19.2 minutes, while solo drivers guessed 11.2 minutes. In the case of SR-55, PeMS data put the average peak hour savings at 2.3 minutes, as compared with carpooler estimates of 17.1 minutes and solo driver estimates of 12.3 minutes. Regarding trips through the I-5/SR-55 connector, speed runs showed peak hour savings of 5.0 minutes, well below average carpooler estimates of 13.8 minutes and solo driver estimates of 12.4 minutes.

Carpool Composition. Another finding common to all of the surveys conducted among Southern California ride-sharers involves the formation and composition of carpools. The vast majority of carpools are formed either with family members or co-workers. In the 2003 survey conducted by SYSTAN for SCAG, an estimated 90% of all carpool lane users reported that they had formed their carpools either with family members (54%) or co-workers (36%). Only 3.3% of all carpoolers surveyed said that company carpool programs had helped with the formation of their carpool, while only 2.2% cited ride matching services.

Reported Changes in Driving Patterns. In all, 10.1% of the solo drivers and 42.9% of the current carpoolers surveyed said that the HOV lanes had caused them to change their driving patterns in some way.

"I changed the time I drive" was the predominant change noted by carpoolers and solo drivers alike reporting a change in response to the presence of carpool lanes. In all, 6.0% of the solo drivers surveyed and 16.0% of the carpoolers reported this change. Among solo drivers in a position to use the SR-55/I-5 interchange, 10.3% reported that the freeway-to-freeway interchange had "caused them to carpool occasionally." While a change attributed to only ten percent of the solo drivers may seem like a small amount, because solo drivers outnumber carpoolers by a significant margin, a small shift in solo driving habits can cause a measurably larger change in carpooling, even if the change is labeled "occasional." Figure 3.59 below breaks down the type of change reported by all responding drivers.



Source: SYSTAN, 2005

Figure 3.59 Self-Reported Impact Of HOV Lanes On Driving Patterns

Carpool Longevity. On the average, ridesharing respondents had been carpooling for 4.5 years. The longest running carpools (4.8 years) were reported by drivers using the SR-55/I-5 connector. Drivers using I-405 and SR-55 reported identical carpool histories, averaging 4.3 years each. This is more than double the carpool longevity reported in 1989 by drivers on similar routes without bus carpool lanes. While the wording of the 1989 surveys did not correspond exactly to that used in the current survey, the sheer magnitude of the differences in longevity before and after the introduction of HOV lanes on the study routes suggests that bus/carpool lanes increase the length of time carpools remain in existence.

Policy Perceptions. When faced with possible changes in policy options affecting carpool definitions, operating hours, and access/egress control, Orange County focus group participants (SYSTAN, 2005) overwhelmingly opted for the status quo. That is, they much preferred 2+ carpool definitions, twenty-four/seven operating hours, and limited access/egress designs. This was true of carpoolers and non-carpoolers alike.

3.7.7 District Twelve Summary

District Twelve's HOV lanes are well utilized, with most operating near full capacity during the peak periods. The introduction of these lanes on freeways has been followed by a gradual growth of ridesharing and an increase in the life span of carpooling and vanpooling arrangements. With the exception of a few instances where the HOV lanes themselves are congested, HOV lanes provide time savings ranging from one minutes to fifteen minutes to rideshare vehicles per trip, averaging 4.2 minutes per trip to vehicles traveling the length of the lanes.

Violation rates average 3.9% throughout the District, well below the 10% level identified as a threshold for concern. Public backing for the HOV lanes is strong, with 76% of the respondents to a 2003 mail-back survey expressing support for carpool lanes. Recent focus groups showed that carpoolers and non-carpoolers alike preferred the current operating policies of 2+ carpool definitions, twenty-four/seven operating hours, and limited access/egress designs.

While carpool lanes on freeways affect congestion and weaving patterns in ways that mixed-flow lanes do not, there is no conclusive evidence that mainline HOV lanes consistently raise or lower accident rates. However, the installation of direct HOV-to-HOV connectors in District Twelve almost universally reduced accident rates in the vicinity of the affected intersections.

CHAPTER FOUR

ASSESSMENT AND DEVELOPMENT OF METHODOLOGIES FOR ESTIMATING AIR QUALITY

4.1 FREQ AIR QUALITY MODULE

The FREQ freeway simulation model includes the prediction of air quality as well as traffic performance. The air quality predictions include hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x) as a function of predicted traffic intensity and performance, vehicle fleet year, ambient temperature, and vehicle classification. The air quality predictions are made for each section of the freeway and for each time interval based on traffic performance predictions and aggregated for the entire freeway study section over the study duration. The previous FREQ air quality prediction module, incorporated in 1991, was based on data produced by the California Air Resources Board's emissions model. This methodology was assessed in light of knowledge gained from the literature review, interviews, and synthesis of current knowledge (Task 1). The previous methodology within the FREQ model was modified and tested to represent the most up-to-date and comprehensive methodology for predicting air quality.

4.1.1 Background

FREQ is a macroscopic freeway simulation model that is based on a supply-demand framework. It analyzes traffic performance over the length of a directional study area and for a given length of time.

The freeway study area is divided into subsections with subsection boundaries being established at any location where there is a change in demand (on-ramp and off-ramps) and /or a change in capacity (e.g. lane drops/adds, significant changes in grade). FREQ allows for up to 160 subsections. The length and number of subsections will vary between study areas, but the number of subsections will generally range from one to three per mile.

The simulation time is comprised of up to twenty-four equal-length time slices. The time slice can be between 1 minute and 60 minutes, but is most commonly 15 minutes. Fifteen-minute time slices allow up to a six-hour FREQ simulation while one-hour time slices would be need for a twenty-four hour study.

The user supplies the geometric design of the freeway, vehicle counts for every on-ramp (including the mainline origin) and every off ramp (including the mainline destination) for each time slice, and the vehicle composition at every on-ramp for each time slice. If an arterial is also being modeled, the subsection boundaries are the same as for the freeway.

Additional information about freeway analysis and the FREQ model can be found in FREQ's new *Freeway Analysis Manual*.

4.1.2 FREQ Air Quality Methodology

FREQ calculates the amounts of hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x) emitted by all vehicles in the freeway corridor. The total emissions produced during the simulation are made up of two components:

1. Emissions from vehicles traveling on the freeway and the arterial

2. Emissions from vehicles delayed at on-ramps and off-ramps

4.1.2.1 Emissions from Vehicles on the Freeway and Arterial

The amount of pollutant, in grams, emitted during a given time slice for a given subsection is calculated by the equation

$$VE_{ip} = VMT_i \sum_c \{f_{ci}\, ER_{cp}(v_i)\}$$

where

i	=	an index specifying one of the two facility types: freeway or arterial
p	=	an index indicating the type of pollutant: HC, CO, or NO_x
c	=	an index specifying the class of vehicles: automobiles, gasoline-powered trucks, or diesel-powered trucks
VE_{ip}	=	the vehicle emissions of pollutant p on the subsection of facility i for the given time slice, in grams
VMT_i	=	the total vehicle miles traveled on the subsection of facility i for the given time
$ER_{cp}(v_i)$	=	the emission rate in grams per mile of pollutant p for a vehicle of type c traveling at an average speed of v_i
v_i	=	the average speed of vehicles traveling on the subsection of facility i during the time slice
f_{ci}	=	the fraction of vehicles of class c on the subsection of facility i

The vehicle fraction f_{ci} is supplied by the user. The vehicle classes are:

1. Autos
2. Gasoline-powered trucks
3. Diesel-powered trucks

The vehicle fraction f_{ci} may vary between subsections for the freeway because the vehicle distribution can be entered for each origin; however, for the arterial f_{ci} is assumed to be constant over all subsections.

The emission rates are provided in tables imbedded in the FREQ model. The tables contain the emission rates for the three pollutants, for each of the three FREQ vehicle classes, at speeds ranging from 5 miles per hour to 70 miles per hour in 5 mile per hour increments. Because the same table is used for both the freeway and the arterial, emissions might be underestimated for the arterial under low speed situations. A more detailed description of these emission rate tables and their development are included in Section 4.2 and Section 4.3.

4.1.2.2 Emissions from Delayed Vehicles

The total emissions generated by vehicles delayed at all freeway ramps during a given time slice is computed as follows:

$$VED_p = TVD \sum_c (f_c\, IER_{cp})$$

where

p	=	an index indicating the type of pollutant: HC, CO or NO_x
c	=	an index specifying the class of vehicle: autos, gasoline-powered trucks, or diesel-powered trucks
VED_p	=	the vehicle emissions from delayed vehicles for pollutant p during the time slice, in grams per minute
TVD	=	the total vehicle delay at the ramps, in vehicle-minutes
f_c	=	the fraction of vehicles in class c, averaged over all freeway subsections
IER_{cp}	=	the idling emission rate in grams per minute of pollutant p for a vehicle of type c

The idling emission rates were obtained by converting the 5 mph rates from grams per mile to grams per minute. These idling factors are included in the emission rate tables imbedded in the FREQ model. A more detailed description of these emission rate tables and their development are included in Section 4.2 and Section 4.3.

4.2 HISTORY OF EMISSION RATES IN THE FREQ MODEL

The original emission rates in the FREQ model were obtained from the Environmental Protection Agency's MOBILE1 computer program, which is described in *User's Guide to MOBILE 1: Mobile Source Emissions Model*. The rates were developed for California vehicles and low-altitude non-California vehicles in 5 mph increments from 5 to 70 mph, with rates for 65 mph and 70 mps estimated by extrapolation. Rates for idling vehicles were also obtained using MOBILE1.

In 1991 a UC Berkeley research project sponsored by FHWA and Caltrans was conducted to improve the emission estimates in the FREQ model as described in *FREQ10 Modification: Emission Factors, Gasoline Consumption, and Growth Factors*. In consultation with Caltrans and the State of California Air Resources Board Emissions Inventory Section (ARB-EIS), a set of twelve emission rate tables were developed and incorporated into FREQ. The emission rates for HC, CO, NO_X were provided by ARB-EIS from their EMFAC7E computer model, which is described in *Methodology to Calculate Emission Factors for On-Road Motor Vehicles*, for three years (1990,1995, and 2010) and four temperatures (55, 65, 85, or 95 degrees Fahrenheit). These tables were user selectable in both the priority lane and priority entry modules of FREQ.

The single most difficult part of developing these twelve tables was reconciling the difference in fleet mix between EMFAC7E and FREQ. A fleet in FREQ is made up of three vehicle classes: autos, gas trucks, and diesel trucks. This mix of vehicles may be determined in the field for existing conditions without stopping vehicles. A more detailed breakdown of the mix of vehicles for a particular site is generally not available to users of the model. A fleet in EMFAC7E was made up of 13 vehicle classes with most of those classes being broken down into additional categories (gas- with no catalytic converter, gas- with catalytic converter, and diesel). The recommended solution was to create a correspondence between the FREQ and EMFAC7E fleets. The emission rates generated by EMFAC7E were weighted by their contribution to the FREQ vehicle class to which they were assigned and then aggregated by FREQ vehicle class.

The fleet mix used in developing the emission rate tables for FREQ in 1991 is shown in Figure 4.1.

FREQ	EMFAC		
Autos	Autos	gas	– non-catalytic
			– catalytic
	Light-duty trucks	gas	– non-catalytic
			– catalytic
Gas trucks	Medium-duty trucks	gas	– non-catalytic
			– catalytic
	Heavy-duty trucks	gas	– non-catalytic
			– catalytic
Diesel trucks	Heavy-duty trucks	diesel	
Omitted from rate calculations	Autos	diesel	
	Light-duty trucks	diesel	
	Buses		
	Motorcycles		

Figure 4.1 Fleet Mix for Developing Emission Rates in FREQ Using EMFAC7 (1991)

The emission factors in the imbedded FREQ tables were based on the following assumptions:

1. The ambient temperature was 55, 65, 85 or 95 degrees Fahrenheit
2. Low altitude conditions prevailed
3. The emission factors apply for vehicles in the calendar years 1990, 1995, or 2010
4. No cars were pulling trailers
5. Both reactive and non-reactive hydrocarbons were included

The emission rates were given for speeds in 5 mph increments, from 5mph to 70 mph. Since EMFAC7E generated rates only for average travel speeds up to 60 mph, the emissions factors for 65 mph and 70 mph were estimated by extrapolation. FREQ used linear interpolation to obtain emission rates for speeds between the 5 mph increments. The idling emission rates were obtained by converting the 5 mph rates from grams per mile to grams per minute.

The user could select from the twelve emissions rate tables that were imbedded in the FREQ model, choosing the one that most closely matched the year and ambient temperature for the study. The FREQ emissions rate table for the year 1990 and an ambient temperature of 65 degrees Fahrenheit is shown in Figure 4.2.

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant														grams /min
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	IDLE
	Hydrocarbons														
Autos	4.28	2.33	1.64	1.29	1.05	0.87	0.73	0.61	0.52	0.47	0.43	0.55	0.93	1.31	0.36
Gas trucks	9.08	5.42	3.72	2.75	2.14	1.71	1.42	1.21	1.06	0.97	0.91	1.03	1.44	1.84	0.76
Diesel trucks	8.24	6.47	5.19	4.26	3.57	3.06	2.68	2.40	2.20	2.06	1.97	1.93	1.93	1.93	0.69
	Carbon Monoxide														
Autos	44.06	22.54	15.42	11.70	9.39	7.82	6.68	5.85	5.24	4.78	4.36	8.40	19.20	30.00	3.67
Gas trucks	105.76	66.40	46.72	35.02	27.69	22.99	20.02	18.31	17.61	17.80	18.80	24.07	35.83	47.59	8.81
Diesel trucks	38.80	26.75	19.30	14.58	11.52	9.53	8.25	7.48	7.09	7.03	7.30	7.94	9.03	10.12	3.23
	Oxides of Nitrogen														
Autos	1.34	1.21	1.11	1.04	0.99	0.95	0.93	0.93	0.94	1.09	1.44	1.78	2.13	2.47	0.11
Gas trucks	3.12	3.07	3.04	3.04	3.06	3.10	3.14	3.20	3.27	3.48	3.88	4.29	4.69	5.09	0.26
Diesel trucks	26.53	22.02	18.92	16.86	15.56	14.88	14.74	15.13	16.09	17.74	20.26	23.97	29.38	34.80	2.21

Figure 4.2. Emission Rates for California Vehicles, 1990 (Hot Stabilized Conditions, Ambient Temperature = 65° F)

4.3. UPDATING THE EMISSION RATES IN THE FREQ MODEL

One of the tasks of this project was to update the air quality module in the FREQ simulation model before applying FREQ to two freeway study areas: one in the North and one in the South. From a review of the literature, it became apparent that the California State Air Resources Board's (ARB) EMFAC model remains the official model for evaluating on-freeway vehicle emissions in California. The official model used in other states is the U.S. Environmental Protection Agency's MOBILE6 Motor Vehicle Emission Factor Model. California developed its own emissions factor model because vehicles in California have stricter emission standards. Vehicles in California also tend to last longer, which results in a vehicle fleet that is different from much of the rest of the country. The EMFAC model has gone through many major revisions since it was used to develop the emission rate factors for FREQ in 1991. These include EMFACE7F, EMFAC7G, EMFAC2000, and EMFAC2002.

The California Air Resources Board's latest version of their EMFAC model, EMFAC2002, was used to update the 1991 emission rate tables incorporated into FREQ. In 1991, the emission rate tables for FREQ were generated by the California Air Resources Board staff in consultation with the UC Berkeley research team; the EMFAC7E model that was used ran on a mainframe and was not available for general distribution. For the current project, EMFAC2002 model was downloaded from the ARB's web site and installed on a PC at UC Berkeley. The new emission rate tables were generated by the UC Berkeley research team with guidance from the California Air Resources Board staff.

EMFAC2002 is a macroscopic model that produces emissions based on average trip speeds, and not on the speed of vehicles on a particular link or the speed of individual vehicles. Because FREQ is a macroscopic model that calculates average speed over the length of the subsections based on traffic flows not individual vehicles, it requires emission rate factors that are based on average speeds. Thus EMFAC2002 emission rates are very compatible with what is required in the FREQ model. FREQ allows for up to 160 subsections, which for most studies would enable the user to divide the subsections into short enough lengths so that the average speed over the subsection could better reflect the changes in speed along the freeway.

4.3.1 Overview of the EMFAC2002 Model

EMFAC2002 is the latest emission inventory model developed by the California Air Resources Board. It calculates emission factors or rates (grams of pollutant emitted over a mile) and vehicle activity (miles driven per day) for motor vehicles operating on California roads. It also calculates an emission inventory (tons per day), which is the product of the emission rate times travel activity times a correction factor. This research project will be using EMFAC2002 output for emission factors and vehicle activity.

The pollutants that EMFAC2002 models are total hydrocarbons (THC)[1], carbon monoxide (CO), oxides of nitrogen (NO_X), carbon dioxide (CO_2), particulate matter (PM)[2], oxides of sulfur (SO_X), and lead (Pb). EMFAC2002 also calculates fuel consumption based on the emissions of CO, CO_2, and THC using the carbon balance equation. This research project will be using emission factors for total hydrocarbons (THC), carbon monoxide (CO), and oxides of nitrogen (NO_X).

EMFAC2002 calculates emissions by emission processes that are dependent on what the vehicles are doing. These include running exhaust, idle exhaust, starting exhaust, running evaporative loss, evaporative loss immediately after a trip, and resting loss. This research project will be using only the EMFAC2002 emission factors for running exhaust. The emission factors that are used will not include running evaporative loss.

The EMFAC2002 model identifies unique technology groups that have distinct emission control technologies. The vehicles in each technology group either have the same emission standards or have equipment installed that makes them behave the same. There are over 200 such technology groups that are used in modeling exhaust emissions and over 30 technology groups used in modeling evaporative emissions. The EMFAC2002 report format used for this project aggregates these groups into broader technology categories: catalyst, non-catalyst, and diesel.

EMFAC2002 models the emissions from all vehicles on the roads in California. This vehicle fleet is divided into 13 vehicle classes. The number of vehicles in each class varies from year to year and by geographic area. The vehicle population used in EMFAC2002 is based on Department of Motor Vehicles registration data for calendar year 1999. Vehicle age matrices

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[1] EMFAC2002 reports Hydrocarbons expressed as total hydrocarbons (THC), reactive organic gases (ROG), total organic gases (TOG), and methane (CH4)

[2] EMFAC2002 reports estimates for total particulate matter (PM), particulate matter 10 microns or less in diameter (PM10) and particulate matter 2.5 microns or less in diameter (PM2.5)

were developed for these years for vehicle class, fuel type, geographic area, and vehicle ages 1 to 45 years. These matrices contain actual population estimates, which are used to back-cast and forecast vehicle populations for calendar years 1970 to 2040. This research project will be using EMFAC2002 to generate emission factors for several years with the geographic area being the entire state.

To run the EMFAC2002 model, users create scenarios in which they specify the geographic area, calendar year, month or season selection, model years of the vehicles included in the calculation, emission mode, and output options.

The material used for this overview of the EMFAC2002 model was extracted from the documentation provided for the EMFAC2002 model: *Emfac2001 version 2.08 / Emfac2002 version 2.20, Calculating emission inventories for vehicles in California, User's Guide* and *EMFAC2002, The Latest Update to the On-Road Emissions Inventory*.

4.3.2 Creating Correspondence Between Vehicle Classes in EMFAC2002 and FREQ

The vehicle classes used in EMFAC2002 were identified. Most of the 13 vehicle class were further subdivided into non-catalytic, catalytic, and diesel. The correspondence between the thirteen vehicle classes and subclasses in EMFAC2002 and the three vehicle classes in FREQ was developed with guidance from California Air Resources Board staff. The fleet mix recommended for developing emission rate tables in FREQ using EMFAC2002 is shown in Figure 4.3.

The first column in Figure 4.3 lists the three FREQ vehicle classes. The columns to the right identify the EMFAC2002 vehicle classes and subclasses assigned to each of the FREQ vehicle classes. This identification information includes the EMFAC2002 vehicle class, the abbreviation used in the model output, the description, weight class, fuel type and fraction of the 2005 VMT that each entry represents. The last column shows the fraction of the 2005 VMT that is assigned to each FREQ vehicle class. The fraction of the 2005 VMT that is assigned to the FREQ vehicle classes is 0.991.

The EMFAC2002 vehicle classes that were not assigned to a FREQ vehicle class are listed and have a total 2005 VMT fraction of 0.01. These classes will be omitted from the calculations used to create the new emission rate tables for FREQ because it was assumed that they would not be driving on the freeway in the same proportion as they are represented in the EMFAC2002 statewide vehicle fleet.

FREQ Vehicle Class	EMFAC2002						
	Vehicle Class	Abbr.	Description	Weight Class	Fuel	Fraction of 2005 VMT	Fraction of VMT Assigned to FREQ12 Class
Autos (includes Light-Duty Vehicles)	1	LDA	Passenger Cars	All	gas-non-catalytic	0.005	
					gas-catalytic	0.542	
					diesel	0.002	
	11	MCY	Motorcycles	All	gas-non-catalytic	0.003	
					gas-catalytic	0.001	
	2	LDT1	Light-Duty Trucks	0-3750	gas-non-catalytic	0.003	
					gas-catalytic	0.139	
					diesel	0.003	
	3	LDT2	Light-Duty Trucks	3751-5750	gas-non-catalytic	0.002	
					gas-catalytic	0.152	
					diesel	0.002	0.854
Gas Trucks	4	MDV	Medium-Duty Trucks	5751-8500	gas-non-catalytic	0.001	
					gas-catalytic	0.065	
	5	LHDT1	Light-Heavy-Duty Trucks	8501-10000	gas-non-catalytic	0	
					gas-catalytic	0.014	
	6	LHDT2	Light-Heavy-duty-Trucks	10001-14000	gas-non-catalytic	0	
					gas-catalytic	0.003	
	7	MHDT	Medium-Heavy-Duty-Trucks	14001-33000	gas-non-catalytic	0	
					gas-catalytic	0.003	
	8	HHDT	Heavy-Heavy-Duty-Trucks	33001-60000	gas-non-catalytic	0	
					gas-catalytic	0.002	0.088
Diesel Trucks	4	MDV	Medium-Duty Trucks	5751-8500	diesel	0.002	
	5	LHDT1	Light-Heavy-Duty Trucks	8501-10000	diesel	0.003	
	6	LHDT2	Light-Heavy-Duty-Trucks	10001-14000	diesel	0.002	
	7	MHDT	Medium-Heavy-Duty-Trucks	14001-33000	diesel	0.012	
	8	HHDT	Heavy-Heavy-Duty-Trucks	33001-60000	diesel	0.03	0.049
Fraction of Total VMT Assigned to FREQ						**0.991**	0.991
	9	LHV	Line-Haul Vehicles	60001 +		0	
Omitted from Calculations	10	UB	Urban Buses	All	gas	0.002	
					diesel	0.002	
	12	SBUS	School Buses	All	diesel	0.001	
	13	MHDT	Motor Homes	All	gas	0.005	
Fraction of Total VMT Not Assigned to FREQ						**0.01**	

Figure 4.3 Fleet Mix for Developing Emission Rates in FREQ Using EMFAC2002

4.3.3 Determining the Parameters for the EMFAC2002 Runs

The parameters used for making the EMFAC2002 runs were determined in close consultation with staff from the California Air Resources Board. It was decided that all runs would be made using "statewide totals", "area average", and a humidity of 40%. The years that were recommended were 1990, 1995, 2000, 2005, 2010, 2015, and 2020; each year was run for 6 different temperatures, 55, 65, 75, 85, 95, and 105 degrees Fahrenheit. Completing these runs resulted in forty-two EMFAC2002 output files.

4.3.4 Methodology for Converting EMFAC2002 Output Files to FREQ Tables

An Excel workbook was developed to automatically convert an EMFAC2002 output file into a table of emission rates factors that would be appropriate for imbedding into the FREQ model.

The Excel workbook contains the following fourteen worksheets:

EMFAC	EMFAC2002 output file
THC TOTALS	Calculation of FREQ total hydrocarbon emission rate factors for Autos & Light Vehicles, Gas Trucks, and Diesel Trucks
CO TOTALS	Calculation of FREQ carbon monoxide emission rate factors for Autos & Light Vehicles, Gas Trucks, and Diesel Trucks
NOx TOTALS	Calculation of FREQ oxides of nitrogen emission rate factors for Autos & Light Vehicles, Gas Trucks, and Diesel Trucks
FREQ table	FREQ emission rate factors in required format for FREQ model
THC-Autos & Lt Vehs	Plots of total hydrocarbon emission rate factors for FREQ Autos and Light Vehicles Class
THC-Gas Trucks	Plots of total hydrocarbon emission rate factors for FREQ Gas Trucks Class
THC-Diesel Trucks	Plots of total hydrocarbon emission rate factors for FREQ Diesel Trucks Class
CO-Autos & Lt Vehs	Plots of carbon monoxide emission rate factors for FREQ Autos and Light Vehicles Class
CO-Gas Trucks	Plots of carbon monoxide emission rate factors for FREQ Gas Trucks Class
CO-Diesel Trucks	Plots of carbon monoxide emission rate factors for FREQ Diesel Trucks Class
NOx-Autos & Lt Vehs	Plots of oxides of nitrogen emission rate factors for FREQ Autos and Light Vehicles Class
NOx-Gas Trucks	Plots of oxides of nitrogen emission rate factors for FREQ Gas Trucks Class
NOx-Diesel Trucks	Plots of oxides of nitrogen emission rate factors for FREQ Diesel Trucks Class

The rest of this section will describe the methodology used to generate the FREQ emission rate factors by describing the process for the following:

- year 2005
- 65 degrees Fahrenheit
- total hydrocarbons
- FREQ Autos and Light Vehicles class

The worksheet labeled EMFAC is used to paste the entire EMFAC2002 output file into the workbook. Figure 4.4 displays a small excerpt taken from this worksheet. It shows five segments that make up the horizontal top section of the worksheet. It begins with a header of general information about the run: the Year is 2005, the Model Years for the fleet are 1965-2005, the State Average is used, the temperature is 65F, and the Relative Humidity is 40%. This excerpt is from Table 1: Running Exhaust Emissions (grams/mile) and includes only the output for Total Hydrocarbons. The speeds are listed along the left side of the first segment from 0 to 70 miles per hour in five mile per hour increments. The EMFAC2002 vehicle classifications listed along the top of each column are:

LDA	Passenger Cars
LDT1	Light-Duty Trucks
LDT2	Light-Duty Trucks
MDV	Medium-Duty Trucks
LHD1	Light-Heavy-Duty Trucks
LHD2	Light-Heavy-Duty Trucks
MHD	Medium-Heavy-Duty Trucks
HHD	Heavy-Heavy-Duty Trucks
LHV	Line-Haul Vehicles
UBS	Urban Buses
MCY	Motorcycles
SBUS	School Buses
MH	Motor Home

Most of the classifications are further divided into NCAT non-catalytic, CAT catalytic, and DSL diesel categories.

Thus in Figure 4.4 the emission rate for a Passenger Car (LDA) with catalytic converter (CAT) traveling as a speed of 40 miles per hour is given as 0.226 grams per mile.

Title : Statewide Totals - Avg 2005 Annual - 65 Degrees (F) - 40% Humidity
Version : Emfac2002 V2.2 Apr 23 2003
Run Date : 01/09/06 16:45:44
Scen Year: 2005 -- Model Years: 1965 to 2005
Season : Annual
Area : Statewide totals
****
Year: 2005 -- Model Years 1965 to 2005 Inclusive -- Annual
Emfac2002 Emission Factors: V2.2 Apr 23 2003

State Average State Average State Average

Table 1: Running Exhaust Emissions (grams/mile; grams/idle-hour)

Pollutant Name: Hydrocarbons Temperature: 65F Relative Humidity: 40%

Speed MPH	LDA NCAT	LDA CAT	LDA DSL	LDA ALL	LDT1 NCAT	LDT1 CAT	LDT1 DSL	LDT1 ALL	LDT2 NCAT	LDT2 CAT	LDT2 DSL	LDT2 ALL
0	0	0	0	0	0	0	0	0	0	0	0	0
5	36.222	1.335	1.24	1.668	36.26	1.617	0.676	2.406	34.908	1.473	0.529	1.882
10	25.795	0.896	0.974	1.134	25.822	1.109	0.531	1.674	24.859	0.998	0.415	1.292
15	19.222	0.632	0.781	0.81	19.242	0.797	0.426	1.22	18.525	0.711	0.333	0.93
20	14.99	0.468	0.641	0.608	15.005	0.6	0.349	0.932	14.446	0.531	0.273	0.703
25	12.232	0.364	0.538	0.478	12.245	0.473	0.293	0.744	11.788	0.415	0.229	0.556
30	10.445	0.296	0.461	0.394	10.456	0.389	0.251	0.622	10.066	0.34	0.196	0.461
35	9.334	0.253	0.404	0.34	9.344	0.335	0.22	0.543	8.995	0.291	0.172	0.399
40	8.728	0.226	0.362	0.308	8.737	0.301	0.197	0.496	8.412	0.261	0.154	0.362
45	8.541	0.212	0.331	0.292	8.55	0.283	0.181	0.474	8.231	0.245	0.141	0.344
50	8.746	0.208	0.31	0.29	8.755	0.277	0.169	0.473	8.428	0.24	0.132	0.342
55	9.371	0.214	0.297	0.301	9.381	0.285	0.162	0.495	9.031	0.247	0.127	0.356
60	10.508	0.231	0.29	0.329	10.519	0.306	0.158	0.542	10.127	0.266	0.124	0.389
65	12.33	0.261	0.29	0.377	12.343	0.345	0.158	0.621	11.883	0.301	0.124	0.444
70	12.33	0.261	0.297	0.377	12.343	0.345	0.162	0.621	11.883	0.301	0.127	0.444

MDV NCAT	MDV CAT	MDV DSL	MDV ALL	LHD1 NCAT	LHD1 CAT	LHD1 DSL	LHD1 ALL	LHD2 NCAT	LHD2 CAT	LHD2 DSL	LHD2 ALL	MHD NCAT
0	0	0	0	47.462	48.979	6.96	41.122	46.123	47.802	6.96	29.323	47.122
39.5	2.064	0.411	2.487	41.486	1.393	1.216	1.58	40.42	2.791	1.554	2.233	61.81
28.129	1.404	0.323	1.709	27.183	0.913	0.955	1.065	26.485	1.828	1.22	1.555	40.5
20.962	1.002	0.259	1.232	18.566	0.623	0.766	0.749	18.09	1.249	0.979	1.128	27.662
16.346	0.75	0.213	0.931	13.218	0.444	0.629	0.548	12.879	0.889	0.803	0.851	19.694
13.339	0.588	0.178	0.737	9.809	0.329	0.527	0.418	9.558	0.66	0.674	0.667	14.615
11.391	0.482	0.153	0.61	7.588	0.255	0.452	0.332	7.393	0.51	0.577	0.541	11.306
10.179	0.414	0.134	0.529	6.119	0.205	0.396	0.274	5.962	0.412	0.506	0.455	9.116
9.518	0.371	0.12	0.479	5.143	0.173	0.355	0.234	5.011	0.346	0.453	0.395	7.662
9.314	0.348	0.11	0.455	4.506	0.151	0.325	0.208	4.39	0.303	0.415	0.354	6.713
9.537	0.342	0.103	0.451	4.115	0.138	0.304	0.191	4.009	0.277	0.389	0.328	6.131
10.219	0.352	0.098	0.469	3.917	0.132	0.291	0.182	3.816	0.263	0.372	0.313	5.836
11.459	0.378	0.096	0.51	3.887	0.13	0.285	0.18	3.787	0.261	0.364	0.308	5.791
13.446	0.427	0.096	0.582	4.02	0.135	0.285	0.184	3.917	0.27	0.364	0.313	5.99
13.446	0.427	0.098	0.582	4.334	0.146	0.291	0.196	4.223	0.292	0.372	0.328	6.458

MHD CAT	MHD DSL	MHD ALL	HHD NCAT	HHD CAT	HHD DSL	HHD ALL	LHV NCAT	LHV CAT	LHV DSL	LHV ALL	UBUS NCAT	UBUS CAT
47.352	6.96	14.97	0	0	6.96	6.556	0	0	0	0	0	0
8.49	1.453	3.376	175.837	41.818	3.345	5.817	0	0	0	0	71.169	24.416
5.563	1.14	2.363	115.216	27.401	2.626	4.22	0	0	0	0	46.633	15.999
3.8	0.915	1.724	78.693	18.715	2.107	3.178	0	0	0	0	31.851	10.927
2.705	0.751	1.307	56.026	13.324	1.729	2.478	0	0	0	0	22.676	7.78
2.008	0.63	1.028	41.578	9.888	1.45	1.996	0	0	0	0	16.828	5.773
1.553	0.54	0.837	32.163	7.649	1.243	1.658	0	0	0	0	13.018	4.466
1.252	0.473	0.705	25.934	6.168	1.089	1.419	0	0	0	0	10.497	3.601
1.053	0.424	0.614	21.798	5.184	0.976	1.25	0	0	0	0	8.823	3.027
0.922	0.388	0.551	19.098	4.542	0.893	1.131	0	0	0	0	7.73	2.652
0.842	0.363	0.511	17.441	4.148	0.836	1.052	0	0	0	0	7.059	2.422
0.802	0.348	0.488	16.603	3.948	0.8	1.006	0	0	0	0	6.72	2.305
0.795	0.34	0.48	16.474	3.918	0.783	0.987	0	0	0	0	6.668	2.288
0.823	0.34	0.487	17.04	4.052	0.783	0.996	0	0	0	0	6.897	2.366
0.887	0.348	0.51	18.372	4.369	0.8	1.033	0	0	0	0	7.436	2.551

Figure 4.4 Excerpt from EMFAC2002 Run – Part 1

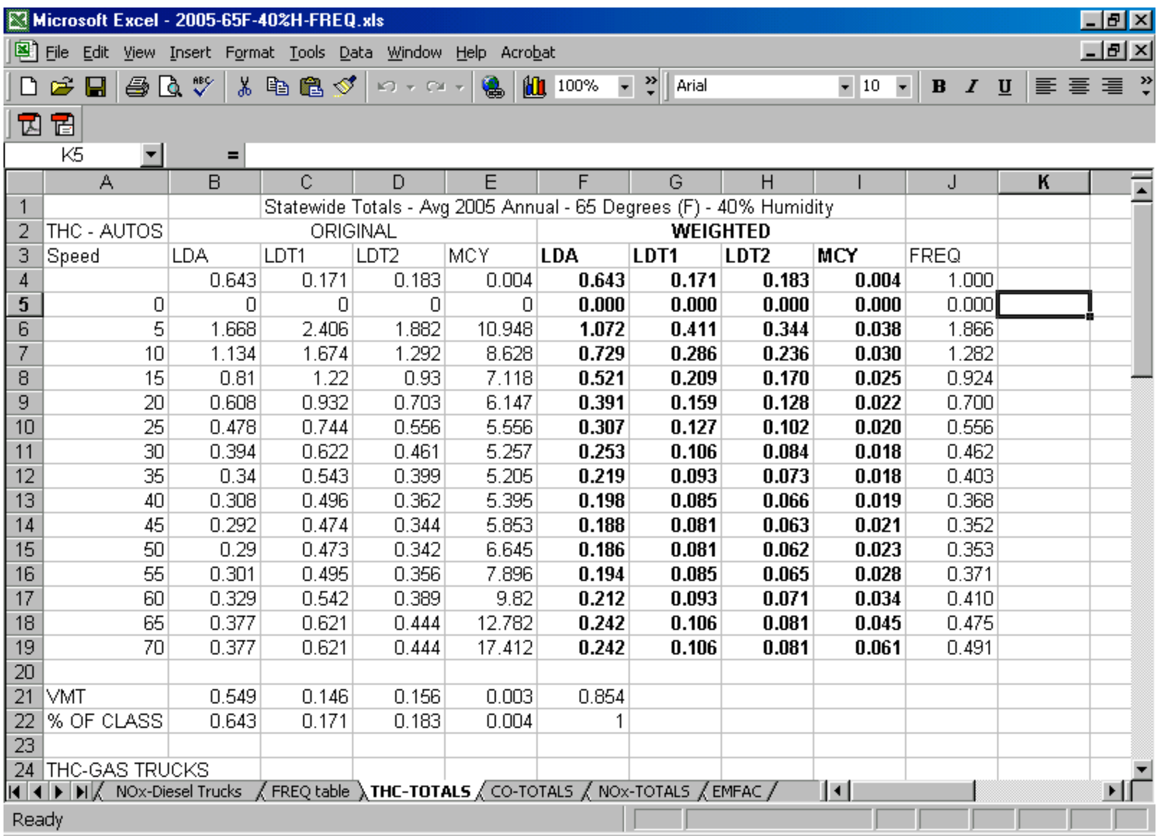
UBUS DSL	UBUS ALL	MCY NCAT	MCY CAT	MCY DSL	MCY ALL	SBUS NCAT	SBUS CAT	SBUS DSL	SBUS ALL	MH NCAT	MH CAT	MH DSL
0	0	0	0	0	0	47.984	46.902	6.96	14.074	0	0	0
4.833	15.875	11.913	6.596	0	10.948	63.107	17.915	1.723	6.303	60.741	7.489	0.819
3.506	10.589	9.409	5.106	0	8.628	41.351	11.739	1.353	4.314	39.8	4.907	0.643
2.634	7.364	7.776	4.149	0	7.118	28.243	8.018	1.086	3.079	27.184	3.351	0.516
2.049	5.339	6.725	3.537	0	6.147	20.107	5.708	0.891	2.289	19.353	2.386	0.423
1.651	4.034	6.086	3.163	0	5.556	14.922	4.236	0.747	1.77	14.362	1.771	0.355
1.378	3.176	5.764	2.967	0	5.257	11.543	3.277	0.64	1.42	11.11	1.37	0.304
1.191	2.605	5.713	2.917	0	5.205	9.308	2.642	0.561	1.182	8.959	1.105	0.267
1.065	2.225	5.924	3.008	0	5.395	7.823	2.221	0.503	1.019	7.53	0.928	0.239
0.987	1.979	6.429	3.25	0	5.853	6.854	1.946	0.46	0.909	6.597	0.813	0.219
0.948	1.833	7.302	3.681	0	6.645	6.259	1.777	0.431	0.839	6.025	0.743	0.205
0.942	1.767	8.677	4.37	0	7.896	5.959	1.692	0.412	0.801	5.735	0.707	0.196
0.97	1.772	10.791	5.437	0	9.82	5.913	1.679	0.403	0.79	5.691	0.702	0.192
1.034	1.85	14.043	7.09	0	12.782	6.116	1.736	0.403	0.805	5.886	0.726	0.192
1.142	2.01	19.124	9.69	0	17.412	6.594	1.872	0.412	0.85	6.346	0.782	0.196

MH ALL	ALL NCAT	ALL CAT	ALL DSL	ALL ALL
0	0.887	1.012	5.632	1.288
12.778	33.859	1.629	2.404	2.171
8.379	24.022	1.097	1.877	1.496
5.727	17.855	0.775	1.5	1.081
4.081	13.907	0.575	1.226	0.819
3.031	11.351	0.446	1.026	0.649
2.346	9.711	0.363	0.878	0.537
1.893	8.708	0.309	0.769	0.466
1.592	8.187	0.275	0.689	0.422
1.395	8.07	0.257	0.631	0.399
1.274	8.342	0.251	0.592	0.395
1.213	9.043	0.256	0.568	0.41
1.204	10.281	0.275	0.557	0.446
1.245	12.26	0.31	0.559	0.508
1.341	13.239	0.313	0.575	0.527

Figure 4.4 Excerpt from EMFAC2002 Run –Part 2

The worksheet THC TOTALS contains all the calculations for determining the FREQ total hydrocarbon emission rate factors for the three FREQ vehicle classifications based on the EMFAC2002 output file and the correspondence between the EMFAC2002 and FREQ vehicle classifications shown in Figure 4.3. Figure 4.5 shows the top section of the worksheet THC TOTAL.

The four EMFAC2002 vehicle class that are included in the FREQ Autos and Light Vehicles class are all passenger cars (LDA), all type 1 light-duty trucks (LDT1), all type 2 light-duty trucks (LDT2), and all motorcycles (MCY). The emission factors for each speed 0 to 70 miles per hour in increment of 5 miles per hour are picked up from the EMFAC worksheet for each entry in their respective columns. The vehicle miles traveled for each of these classes are also picked up from the EMFAC worksheet for each of the EMFAC2002 classes. These are shown in row 21. The percent of the FREQ vehicle class that each EMFAC2002 class represents is calculated by dividing the VMT by the total of the VMT. Thus for passenger cars the percent of class is 0.643 [0.549 / (0.549+0.146+0.156+0.003)]



	A	B	C	D	E	F	G	H	I	J
1			Statewide Totals - Avg 2005 Annual - 65 Degrees (F) - 40% Humidity							
2	THC - AUTOS		ORIGINAL				WEIGHTED			
3	Speed	LDA	LDT1	LDT2	MCY	**LDA**	**LDT1**	**LDT2**	**MCY**	FREQ
4		0.643	0.171	0.183	0.004	**0.643**	**0.171**	**0.183**	**0.004**	1.000
5	0	0	0	0	0	**0.000**	**0.000**	**0.000**	**0.000**	0.000
6	5	1.668	2.406	1.882	10.948	**1.072**	**0.411**	**0.344**	**0.038**	1.866
7	10	1.134	1.674	1.292	8.628	**0.729**	**0.286**	**0.236**	**0.030**	1.282
8	15	0.81	1.22	0.93	7.118	**0.521**	**0.209**	**0.170**	**0.025**	0.924
9	20	0.608	0.932	0.703	6.147	**0.391**	**0.159**	**0.128**	**0.022**	0.700
10	25	0.478	0.744	0.556	5.556	**0.307**	**0.127**	**0.102**	**0.020**	0.556
11	30	0.394	0.622	0.461	5.257	**0.253**	**0.106**	**0.084**	**0.018**	0.462
12	35	0.34	0.543	0.399	5.205	**0.219**	**0.093**	**0.073**	**0.018**	0.403
13	40	0.308	0.496	0.362	5.395	**0.198**	**0.085**	**0.066**	**0.019**	0.368
14	45	0.292	0.474	0.344	5.853	**0.188**	**0.081**	**0.063**	**0.021**	0.352
15	50	0.29	0.473	0.342	6.645	**0.186**	**0.081**	**0.062**	**0.023**	0.353
16	55	0.301	0.495	0.356	7.896	**0.194**	**0.085**	**0.065**	**0.028**	0.371
17	60	0.329	0.542	0.389	9.82	**0.212**	**0.093**	**0.071**	**0.034**	0.410
18	65	0.377	0.621	0.444	12.782	**0.242**	**0.106**	**0.081**	**0.045**	0.475
19	70	0.377	0.621	0.444	17.412	**0.242**	**0.106**	**0.081**	**0.061**	0.491
20										
21	VMT	0.549	0.146	0.156	0.003	0.854				
22	% OF CLASS	0.643	0.171	0.183	0.004	1				
23										
24	THC-GAS TRUCKS									

Figure 4.5 Top Section of Worksheet for Calculating Total Hydrocarbon FREQ Emission Rate Factors for Autos and Light Vehicles

The WEIGHTED emission rate factors in Figure 4.5 are shown for each EMFAC2002 vehicle class included in this FREQ vehicle class. Each entry is calculated by multiplying the corresponding ORIGINAL entry by the % OF CLASS. Thus for passenger cars traveling at 40 miles an hour the calculation is: 0.308 * 0.643 = 0.198. Finally the actual FREQ emission rate factor for each speed is the total across the WEIGHTED entries for that speed. Thus the emission rate factor for the FREQ Autos and Light Vehicles class at 40 miles per hour is 0.368 [0.198 + 0.085 + 0.066 + 0.019].

Figure 4.6 displays worksheet “FREQ table” which is the completed emission rate factors table in the format required for the FREQ model. Note that the table contains the emission rate factors for all three pollutants: total hydrocarbons, carbon monoxide, and oxides of nitrogen. All entries are picked up from the three calculation worksheets: THC TOTALS, CO-TOTALS, and NOx TOTALS.

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2005 Annual - 65 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant														grams/ minute
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	"IDLE" *
Total Hydrocarbons															
Autos	1.866	1.282	0.924	0.700	0.556	0.462	0.403	0.368	0.352	0.353	0.371	0.410	0.475	0.491	0.155
Gas trucks	3.530	2.377	1.675	1.236	0.954	0.770	0.651	0.575	0.532	0.515	0.523	0.555	0.619	0.631	0.294
Diesel trucks	2.558	2.008	1.612	1.322	1.109	0.951	0.833	0.747	0.683	0.639	0.612	0.599	0.599	0.612	0.213
Carbon Monoxide															
Autos	9.726	8.125	6.975	6.123	5.483	4.999	4.639	4.386	4.233	4.185	4.264	4.509	4.999	5.211	0.811
Gas trucks	17.996	13.462	10.593	8.712	7.446	6.586	6.015	5.667	5.514	5.557	5.825	6.386	7.371	8.037	1.500
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809
Oxides of Nitrogen															
Autos	0.900	0.778	0.688	0.624	0.579	0.548	0.529	0.520	0.521	0.533	0.554	0.588	0.638	0.643	0.075
Gas trucks	1.769	1.601	1.487	1.411	1.363	1.339	1.333	1.342	1.367	1.407	1.462	1.537	1.635	1.657	0.147
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Figure 4.6 FREQ Emission Rate Factors Table for Total Hydrocarbons

The “IDLE” emission factors shown in Figure 4.6 are calculated by converting the 5 mile per hour emission rate factors (grams per mile) to grams per minute. These values better represent the emissions emitted by “creeping” vehicles delayed at the ramps than the idle values that are calculated by EMFACT2002. The EMFAC2002 idle values calculate the emissions emitted by trucks that are idling for long periods of time while loading or merely parked with the motor running.

The remaining worksheets contain plots for the individual pollutants and FREQ vehicle classes. The worksheet “THC-Autos & Lt Vehs” is shown in Figure 4.7. The “WEIGHTED” emission rate factors for each of the EMFAC200 vehicle classes that make up the FREQ Autos and Light Vehicles class are plotted along with the final FREQ emission rate factors. The legend shown the percent of the FREQ vehicle class each of the EMFAC2002 vehicle class represents.

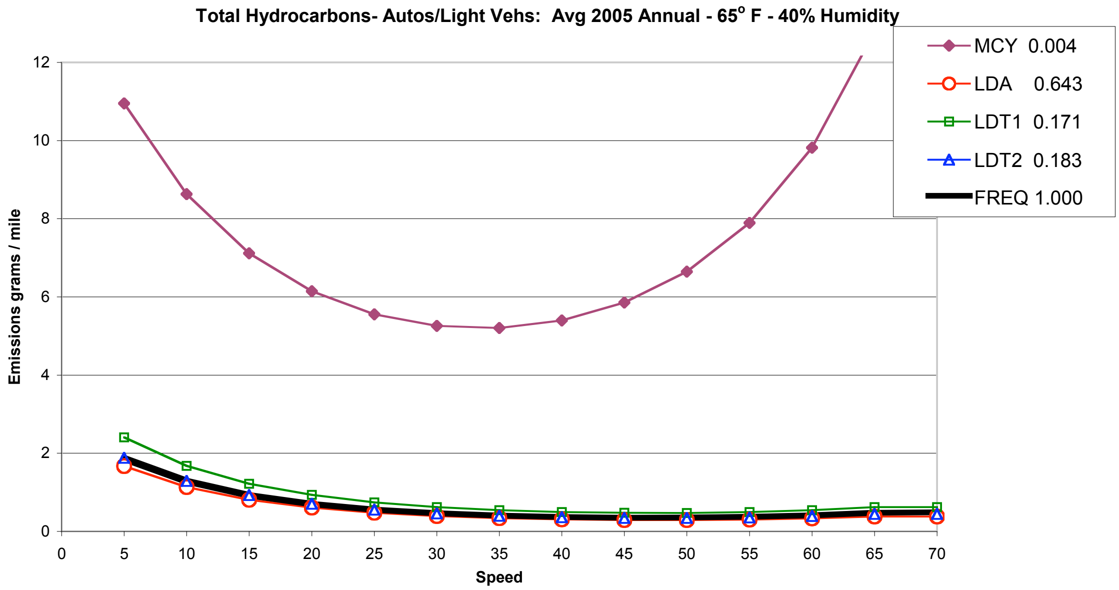


Figure 4.7 Plots of the Vehicle Class for the FREQ Autos and Light Vehicle Class

The initial Excel workbook was developed in such a way that each additional workbook could be created by pasting the EMFAC2002 output file into the EMFAC worksheet. All calculations for a new scenario would then occur automatically. In this way all forty-two emission rate tables for FREQ were created.

4.3.5 Modifying the FREQ Model

The forty-two new emission rate tables were incorporated into the existing FREQ air quality module. The logic of this module is described previously in Section 4.1.2. The tables from the old EMFAC7E model were kept in FREQ for testing and research purposes. The user can now select from either set of emission rate tables.

4.4 EMISSION RATE TABLES FOR PeMS OFF-LINE AIR QUALITY MODULE

Emission rate tables were created for use in the PeMS off-line air quality module developed and demonstrated as part of Task 4 which is described in Chapter 5. Tables for three pollutants, HC, CO and NO_x were developed using the latest version of the California Air Resources Board emissions model, EMFAC2002. These tables contain the emission rate for the pollutant in grams per mile at a given speed.

Two sets of tables were developed. The first one contained emission rates for speeds from 5 to 70 miles per hour in increments of 5 miles per hour. The second one contained emission rates for speeds from 1 to 70 miles per hour in increments of 1 mile per hour. As for the FREQ tables, the "IDLE" emission factors were calculated by converting the 5 mile per hour emission rate factor (grams per mile) to grams per minute. Both sets of tables were developed using the following parameters for the EMFAC2002 runs:

State-wide-average 2006 emission rates for state-wide vehicle fleet
75 degrees Fahrenheit and 40% humidity

CHAPTER FIVE

APPLICATION OF MODIFIED FREQ MODEL TO EVALUATE HOV LANES

5.1 INTRODUCTION

This introduction contains three sections. The first section provides a description of the project's Task 4 "Application of Modified FREQ Model to Evaluate HOV Lanes". The final two sections describe the selection of the two application study sites and a guide to the organization of the remaining portions of this chapter.

5.1.1 TASK 4 DESCRIPTION

The project's proposal and the contract contained the following description of the project's Task 4:

"The modified FREQ model will be applied to two freeway study sections for the purposes of demonstrating and providing an assessment of the effectiveness of HOV lanes and their impact on air quality. One site will represent typical northern California practice (peak-period only, unlimited HOV lane access, and associated cut-off levels) while the other site will represent southern California practice (24/7, limited HOV lane access, and associated cut-off levels). The assessment will include vehicular and personal travel in the HOV lane and adjacent mixed-flow lanes as well as air quality consequences.

Sensitivity analysis would be undertaken to assess the consequences on vehicular/person travel and air quality. The HOV lane sensitivity parameters would include such elements as HOV lane location, priority cut-off level or occupancy requirement, design, access/egress limitations, growth consequences, and traffic intensity level.

Documentation would be provided that will describe the process followed and the results obtained in these two demonstration applications".

The actual work on this task has followed the initial task description with little deviation.

5.1.2 SELECTION OF APPLICATION SITES

The initial steps in the selection of application sites were to identify the criteria for selection and to evaluate leading candidate sites. The criteria included the following:

- One site from northern California (unlimited HOV lane access, peak period operations)
- One site from southern California (limited HOV lane access, 24/7 operations)
- Existing FREQ calibrated data set
- Quality of the data
- Quality of the calibration
- Sufficient congestion so that the prospect of an HOV lane's success is realistic
- Operating issues a key concern for sensitivity analysis
- Level of district involvement and interest
- Project staff previous experience with site studies

Candidate sites were identified and evaluated in terms of these criteria on a district-by-district basis and a summary of these results are presented in Figure 5.1. After further review of these various candidate sites, the two sites that best met the selection criteria were recommended: I-580 in the north (district 04) and I-210 in the south (district 07).

Senior staff members in headquarters, district 04, and district 07 were contacted to seek their advice in regard to the recommended two sites and the consensus was acceptance of these two sites for the purpose of the demonstration applications. It should be made clear to the reader that the intent of these investigations is for demonstration purposes and not implementation.

5.1.3 CHAPTER ORGANIZATION

The remaining three parts of this chapter include the following:

- Demonstration Application on the Northern California Site
- Demonstration Application on the Southern California Site
- Summary Highlights

RANK	DISTRICT	FREEWAY	QUALITY OF DATA	CALIBRATED DATA SET	COMMENTS
	01				**Few freeways and little current interest.**
	02	I-5	Good	yes	Calibrated data set available based on 2002 data through Redding, but with **little congestion**. **Doubtful of district support.**
	03			?	Several FREQ applications in past years, but not sure of calibration. Some current efforts underway with Paramics model which might provide input data sets, but calibration would be necessary. **Would need strong district support, if selected for HOV project**
1	04	I-580 I-680 US 101	Good Good	yes yes	Research team has experience with data set that was collected as part of the Paramics project. Data set is well documented in Freeway Analysis Manual. Data collected in 2002. **Leading site.** Research team has some experience with data set that was collected as part of the Paramics project Near Redwood City. Not sure of quality of the data set or calibration.
2	05	SR-1	Good	yes	Excellent district cooperation and research team has close working relationship with District. Three data sets: Near Santa Cruz, Salinas, and San Luis Obispo. **Santa Cruz** data set is the best one and based on current project that research team has been working on for some time. They expect to start a new project in Santa Barbara soon that has a high priority for them. **Leading site and would expect district support.**
2	06	14 sites	Good	yes	Excellent district cooperation and research team has close working relationship with District. Data sets for fourteen directional peak periods. Data sets at least two years old. Best data set from this district would be **leading site.**

Figure 5.1 Candidate Sites for FREQ Applications (part 1)

RANK	DISTRICT	FREEWAY	QUALITY OF DATA	CALIBRATED DATA SET	COMMENTS
1	07	I-210	Good	yes	Through Pasadena. Research team has experience with data set that was collected as part of the Paramics project and access to additional data that was used during calibration. **Leading site.**
		SR-118			Data is probably several years old.
	08	I-10	?	?	Good district cooperation and research team has fairly close working relationship with supervisor. Turnover of staff and staff lack of experience has slowed down current applications. **Would need strong district support, if selected for HOV project.**
	09				**Few freeways and little current interest.**
	10	I-205		yes	Good district cooperation and research team has fairly close working relationship with district. Data set through Tracy several years old. There are current efforts being considered for further FREQ application district-wide. **Would need strong district support, if selected for HOV project.**
	11	I-5			Good district cooperation, but not high priority by supervisors. Have worked with them for several years, but their staff keeps getting rotated off and on the project. **Would need strong district support, if selected for HOV project.**
	12	I-5		?	Coded but not sure of quality of calibration.
2		SR-91			Currently working with Orange County Transportation Authority, but they are in early stages of calibration. **Leading site, depending on Orange County support.**

Figure 5.1 Candidate Sites for FREQ Applications (part 2)

5.2 DEMONSTRATION APPLICATION ON THE NORTHERN CALIFORNIA SITE

The objective of these investigations is to demonstrate the application of the FREQ model to investigate adding an HOV lane to the existing I-580 eastbound freeway during the afternoon peak period between the I-680 freeway and the I-205 freeway through a series of sensitivity-type computer runs. This portion of the chapter deals with the I-580 site and is divided into the following four parts:

- I-580 freeway performance under 2004 traffic conditions
- HOV lane design parameters and their selection
- Investigations of added HOV lane for 3+ vehicles
- Investigations of added HOV lane for 2+ vehicles

5.2.1 PREDICTED I-580 FREEWAY PERFORMANCE UNDER 2004 TRAFFIC CONDITIONS

The eastbound I-580 freeway study section extends from just west of the I-680 freeway to the junction with I-205. The study section was 28 miles long and divided into 36 subsections while the study time duration was from 2 to 7 pm and was divided into 20 15-minute time periods. The design features of the 36 subsections that make up the study section are shown in Figure 5.2. The number of lanes, capacities, lengths, and other pertinent input data are shown for each of the 36 subsections.

The freeway design features, traffic counts, and other supporting data was entered into the FREQ model to represent the freeway conditions prior to the consideration of adding an HOV lane. There was no ramp entry control on the freeway. A comprehensive calibration and validation process was followed by making minor adjustments to the input data so that the model predictions fairly closely represented actual field conditions. The details of assembling input data, coding the input, making a computer run, and calibrating/validating the model are covered in the FREQ's "Freeway Analysis Manual".

The freeway summary table of simulation results before implementation of an HOV lane is shown as Figure 5.3. Each horizontal row represents each of the 20 15-minute time periods over the length of the study section and the totals for the entire study duration period and the entire study section are shown at the bottom of the figure. As can be seen from this figure, a total of 20,906 passenger-hours are expended on the freeway, 62 passenger-hours represented freeway entry delays, and 20,968 passenger-hours was the grand total time expended. The total travel on the freeway during the peak period was 1,006,723 passenger-miles and the overall average speed was 48.2 mph. Total fuel consumed and vehicle emissions (HC, CO, and Nox) were 39,219 gallons, 246 kilograms, 2968 kilograms, and 284 kilograms respectively. These are the principal measures of effectiveness that can be used in evaluating the effects of adding the HOV lane.

The freeway congestion pattern is shown in Figure 5.4. Freeway traffic is moving from left to right and peak period time is depicted on the vertical scale with time going down the page. The asterisks indicate the location of freeway congestion over time and space, and the two bottlenecks causing the congestion are in subsections 19 and 32. Unfortunately the freeway congestion extends beyond the last time slice and the statistics provided in the previous paragraph slightly underestimate the total effects of freeway congestion. Later it will be shown that this will result in slightly under-estimating the full effects of adding the HOV lane.

FREEWAY AND ARTERIAL DESIGN FEATURES

SUB SEC	NO. LNS	SSEC CAP	SSEC LENGTH	DESIGN SPEED	ORG DES	TRK FAC	SSEC GRAD	PCT TRK	PCT DES TRUCKS	SPECIAL RAMP	FF.SPD. ALT.RTE	CAP. ALT.RTE	ART TYPE	GRADE ALT.RTE	SUBSECTION LOCATION
1	4	7200.	4514.	65	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Mainline - Eden Off
2	4	7200.	4515.	65	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	SECOND HALF OF SPLIT SS
3	4	7200.	2592.	65		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Eden Off - Eden On
4	4	7200.	4533.	65	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Eden On - San Ramon Off
5	4	7200.	1257.	65		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	RamonOff - Ramon On
6	5	9000.	947.	65	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Ramon On - I680 Off
7	4	7200.	2159.	65	D	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	I680 Off - Hopyard Off
8	4	7200.	929.	65		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Hopyard Off - LaneDrop
9	3	5400.	1565.	65		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	LaneDrop - I680 SB On
10	5	9000.	277.	65	O	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	I680 SB On - I680 NB On
11	6	10800.	1139.	65	O	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	I680 NB On - Hop 1 On
12	7	12600.	870.	65	O	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Hop 1 On - Hop 2 On
13	7	12600.	3456.	65	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Hop 2 On - Hacienda Off
14	5	9000.	1223.	65		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Haci Off - Hacienda 1 On
15	6	10800.	955.	65	O	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Haci 1 On - Haci 2 On
16	6	10800.	2304.	65	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Haci 2 On - Tass Off
17	4	7200.	1298.	65		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Tass Off - Tass 1 On
18	4	7200.	1149.	65	O	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Tass 1 On - Tass 2 On
19	4	7100.	5127.	65	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Tass 2 On - Charro Off
20	4	7200.	2054.	65		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Charro Off - Charro 1 On
21	4	7600.	7874.	65	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Char 2 On - Airway Off
22	4	7200.	937.	65		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Airway Off - Airway On
23	4	7600.	9859.	65	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Airway On - Portola Off
24	4	7200.	3236.	65	D	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Portola Off - Liver Off
25	4	7200.	1798.	65		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Liver Off - Liver On
26	4	7200.	9033.	65	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Liver On - SR84 Off
27	4	7200.	1676.	65		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	SR84 Off - SR84 On
28	4	8000.	4016.	65	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	SR84 On - Vasco Off
29	4	7200.	2328.	65		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Vasco Off - Vasco On
30	4	7200.	4772.	65	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Vasco On - Green Off
31	4	7200.	815.	65		0.69	4.0	5	50	NO	0.0	0.	GOOD	0.0	Green Off - Green On
32	4	6450.	12994.	65	OD	0.69	4.0	5	50	NO	0.0	0.	GOOD	0.0	Green On - Flynn Off
33	4	7200.	1948.	65		0.95	-4.0	5	50	NO	0.0	0.	GOOD	0.0	Flynn Off - Flynn On
34	4	7200.	23222.	65	OD	0.95	-4.0	5	50	NO	0.0	0.	GOOD	0.0	Flynn On - Grant Off
35	4	7200.	1862.	65		0.74	2.9	5	50	NO	0.0	0.	GOOD	0.0	Grant On - Grant Off
36	4	7200.	5280.	65	OD	0.95	-3.0	5	50	NO	0.0	0.	GOOD	0.0	Grant On - I580 Off
37	3	5400.	1320.	65	D	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	I580 Off - Mainline Out
38	3	5400.	1320.	65	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	SECOND HALF OF SPLIT SS

Figure 5.2 I-580 Freeway Design Features

FREEWAY SUMMARY TABLE
SIMULATION BEFORE IMPLEMENTATION OF PRIORITY LANE

TIME SLICE	FREEWAY TRAVEL TIME		RAMP DELAY		TOTAL FREEWAY TRAVEL TIME		TOTAL TRAVEL DISTANCE		AVERAGE SPEED	GASOLINE CONSUMED	HYDROCARB EMISSIONS	CARBON MONOXIDE	NITROUS OXIDES	BEGIN TIME
	VEH-HR	PAS-HR	VEH-HR	PAS-HR	VEH-HR	PAS-HR	VEH-MI	PAS-MI	MPH	GALLONS	KILOGRAMS	KILOGRAMS	KILOGRAMS	
1	560.	705.	0.	0.	560.	705.	35530.	44768.	63.5	1829.	11.	133.	13.	14:00
2	616.	776.	0.	0.	616.	776.	37922.	47781.	61.6	1924.	12.	141.	14.	14:15
3	674.	849.	0.	0.	674.	849.	39507.	49779.	58.7	1948.	12.	144.	14.	14:30
4	700.	882.	0.	0.	700.	882.	39847.	50208.	57.0	1965.	12.	146.	14.	14:45
5	744.	938.	0.	0.	744.	938.	40631.	51195.	54.6	1948.	12.	147.	14.	15:00
6	775.	977.	0.	0.	775.	977.	41287.	52022.	53.3	1973.	12.	149.	14.	15:15
7	795.	1002.	8.	10.	803.	1012.	41006.	51667.	51.6	1961.	12.	148.	14.	15:30
8	858.	1081.	13.	17.	871.	1098.	42031.	52959.	49.0	1992.	12.	152.	15.	15:45
9	891.	1122.	13.	16.	904.	1139.	41476.	52260.	46.6	1986.	12.	152.	15.	16:00
10	903.	1138.	11.	14.	914.	1152.	41116.	51806.	45.5	1988.	13.	152.	14.	16:15
11	957.	1206.	4.	5.	961.	1211.	41278.	52010.	43.1	1989.	13.	153.	14.	16:30
12	952.	1199.	0.	0.	952.	1199.	40687.	51266.	42.7	1983.	13.	153.	14.	16:45
13	968.	1220.	0.	0.	968.	1220.	40952.	51600.	42.3	1985.	13.	153.	14.	17:00
14	990.	1248.	0.	0.	990.	1248.	41537.	52336.	41.9	2010.	13.	155.	15.	17:15
15	993.	1251.	0.	0.	993.	1251.	41170.	51874.	41.5	2003.	13.	155.	15.	17:30
16	925.	1166.	0.	0.	925.	1166.	40474.	50997.	43.7	1989.	13.	152.	14.	17:45
17	910.	1147.	0.	0.	910.	1147.	40823.	51437.	44.8	1995.	13.	152.	14.	18:00
18	866.	1091.	0.	0.	866.	1091.	39891.	50263.	46.1	1987.	13.	150.	14.	18:15
19	780.	983.	0.	0.	780.	983.	36598.	46113.	46.9	1917.	12.	143.	14.	18:30
20	735.	926.	0.	0.	735.	926.	35224.	44382.	47.9	1847.	12.	137.	13.	18:45
TOTAL	16592.	20906.	49.	62.	16642.	20968.	V-M: 798987.	P-M: 1006723.	48.2	39219.	246.	2968.	284.	

Figure 5.3 I-580 Freeway Performance Without Added HOV Lane

```
CONTOUR DIAGRAM OF
QUEUE LENGTH                ALL LANES
BEFORE  IMPLEMENTATION

        TIME                                                                                                     BEGIN
        SLICE .....................................................................................................   TIME
              .                                                                                                   .
            1 .                                                                                                   . - 14:00
            2 .                          ***                                                                      . - 14:15
            3 .                          ***                                                                      . - 14:30
            4 .                         ****                                                                      . - 14:45
            5 .                         ****                                                                      . - 15:00
            6 .                        *****                                      *                               . - 15:15
            7 .                       ******                                      *                               . - 15:30
            8 .                      *******                                    ***                               . - 15:45
            9 .                      *******                                  *****                               . - 16:00
           10 .                     ********                                  *****                               . - 16:15
           11 .                     ********                              *********                               . - 16:30
           12 .                     ********                               ********                               . - 16:45
           13 .                     ********                              *********                               . - 17:00
           14 .                    *********                                *******                               . - 17:15
           15 .                   **********                                *******                               . - 17:30
           16 .                    *********                                    ***                               . - 17:45
           17 .                   **********                                      *                               . - 18:00
           18 .                    *********                                                                      . - 18:15
           19 .                    *********                                                                      . - 18:30
           20 .                     ********                                                                      . - 18:45
              .                                                                                                   .
              .....................................................................................................
               :  :  : :  ::: ::::::  ::: :::   ::     ::      : ::      ::  : :  ::        ::             ::    ::
               01 02 0304   07     13   16  19   21     23     24 26      28 2930  32        34             36

         BLANK DENOTES MOVING TRAFFIC.  ASTERISK DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION.
         M  DENOTES QUEUED VEHICLES DUE TO MERGING.  B  DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION AND
         MERGING.   (WHEN BOTH QUEUES EXIST, LENGTH OF DISPLAY REPRESENTS MAINLINE CONGESTION.)
```

Figure 5.4 I-580 Freeway Congestion Pattern Without Added HOV Lane

5.2.2 HOV LANE DESIGN PARAMETERS AND THEIR SELECTION

The principal issues to be addressed in the design of freeway HOV lanes include the following:

- Number of HOV lanes
- HOV cut-off limits
- Length and placement of HOV lane
- Time of HOV operations
- HOV barriers
- Vehicle occupancy distribution
- Anticipated growth

5.2.2.1 Number of HOV Lanes

A single lane HOV lane will normally have a capacity on the order of 1500 vehicles per hour but may vary from 1200 to 1800 vehicles per hour per lane depending upon the local situation. If a freeway carries less than 1200 HOV-qualified vehicles per hour, a single-lane HOV lane is often adequate. A practical limitation is right-of-way restrictions and even adding one additional HOV lane is often very difficult. If there are right-of-way restrictions and the HOV demand is over 1200 vehicles per hour, an alternative is to introduce HOV barriers that will limit the HOV lane usage to be below the HOV lane capacity. For purposes of these demonstration investigations, it will be assumed that only one added HOV lane is considered.

It was later learned that District 04 uses 1650 vph not the current FREQ default value of 1500 vph for the capacity of a single HOV lane. Increasing the capacity of a single HOV lane would extend the reported effectiveness of 2+ cutoff design to higher percentages of 2+ occupancy levels.

5.2.2.2 HOV Cut-Off Limits

The vehicle cut-off limits for HOV lane usage must obviously be an integer value and the options are 2+, 3+, 4+, or buses only depending on many factors including the vehicle occupancy distribution. The most common cut-off limit is either 2+ or 3+ with a 2+ limit possibly overloading the HOV lane and the 3+ limit possibly causing under-utilization the HOV lane.

Since cut-off limits of 2+ and 3+ are the leading cut-off limit candidates, a cut-off limit of 3+ will be considered in the first portion of this section and a cut-off limit of 2+ will be considered in the second portion of this of this section.

5.2.2.3 Length and Placement of HOV Lane

The length and placement of the HOV lane are very important design parameters. As a minimum, it is desirable for the HOV lane to extend far enough upstream so that HOV vehicles can bypass the congestion in the non-HOV lanes under current and near-term future traffic demands. It should also extend far enough downstream so HOV vehicles can re-enter the non-HOV lanes under free-flow conditions under current and near-term future traffic demands.

In the event of two separate freeway bottlenecks, one could consider separate short HOV lanes for both or either of the bottlenecks or a longer HOV lane covering both freeway bottlenecks. Adding an HOV lane around only the upstream bottleneck, may provide some benefits but will likely cause increased congestion at the downstream bottleneck. Adding an HOV lane around the downstream bottleneck only will improve freeway conditions and provide some benefits but will do little for relieving the upstream bottleneck.

The longer the HOV lane, the greater effectiveness of the HOV lane and the incentive for persons in lower occupancy vehicles to join those in vehicles qualified to use the HOV lane. Since the two major bottlenecks and resulting congestion almost overlap, only an HOV lane over the complete length of the freeway study sections was considered.

5.2.2.4 Time of HOV Operations

The time of HOV operations can vary from a limited period of time such as a peak period to a complete 24-hour day. Because of limited traffic data available, only HOV operations during the peak period will be considered in these investigations. It is also current district practice to operate HOV lanes only during peak periods.

5.2.2.5 HOV Barriers

Continuous or intermittent HOV barriers can be placed between the HOV lane and the non-HOV lanes to restrict the number of HOV vehicles using the HOV lane. Such barriers are more likely to be used when the HOV lane demand approaches or exceeds the HOV lane capacity such as with higher percentages of HOV-qualified vehicles. Barriers have also been introduced for safety reasons. The investigations undertaken will demonstrate that there are some operational merit in introducing intermittent barriers when cut-off limits of 2+ are considered but little operational merit when cut-off limits of 3+ are considered.

5.2.2.6 Vehicle Occupancy Distribution

A significant factor in the design and the success of HOV operations is the vehicle occupancy distribution. A typical vehicle distribution for California freeways is 80% single-passenger vehicles, 15% of vehicles carrying two persons, 5 percent of vehicles carrying 3 or more persons, and essentially no or few buses. There may be considerable variation in vehicle occupancy distributions over time and between freeway entrances as well as between freeway sites.

It is not easy to obtaining vehicle occupancy distribution data over time and by individual freeway entrance. When such data is collected, it is often not accurately obtained. One of the objectives of HOV operations is to encourage carpooling and thus the vehicle occupancy distribution would be expected to change. Therefore for these investigations one of the two important factors to be varied in the sensitivity analysis is vehicle occupancy distribution.

5.2.2.7 Anticipated Future Growth

Freeway traffic demands change by time of year and particularly change over years between the time the HOV lane study is undertaken and the time the HOV lane is implemented as well as during the initial years of HOV operations. Changing freeway traffic demands will have a significant impact on the success of an HOV lane operation. Therefore in these investigations one of the two important factors to be varied in the sensitivity analysis is anticipated future growth.

5.2.3 INVESTIGATIONS OF ADDED HOV LANE FOR 3+ VEHICLES

As discussed in the previous section, the following investigations of an added HOV lane will initially assume the following:

- Single added HOV lane

- HOV cut-off limit of 3+
- HOV lane over the entire study section
- Peak period operations only
- No HOV barrier
- Typical vehicle occupancy distribution
- 2004 freeway demand level

Further investigations of the first five assumptions will be undertaken if deemed desirable and sensitivity analysis will be undertaken of vehicle occupancy distribution and freeway demand level. The percent of vehicles carrying 3+ persons will vary from 2% to 10% with an initial value of 5%. The freeway demand level will vary from 0.95 to 1.10 with an initial value of 1.00 representing the year 2004 freeway demand level. For example, to incorporate a freeway demand level of 1.10, all freeway entrance and exit traffic counts entered in the base run were multiplied by a constant factor of 1.10.

5.2.3.1 Effect of Adding the HOV Lane

A summary table showing the differential effects of adding the HOV lane to this study section is shown in Figure 5.5. The measures of effectiveness are shown in the first two columns; the performance measures before the implementation of the HOV lane are shown in the next three columns; the performance measures after the implementation of the HOV lane are shown in the next three columns; and the differences in performance measures are shown in the final four columns. Note that this investigation is limited to the freeway only and does not include the modeling of the arterial routes.

The adding of the HOV lane has reduced total passenger-hours by 20%, increased passenger-miles served by over 1%, increased average overall freeway speed by 26%, increased fuel consumption by 1 percent, reduced HC emissions by 3 percent, reduced CO emissions by 1%, and increased Nox emissions by 1 percent.

5.2.3.2 Sensitivity Analysis of Vehicle Occupancy Distribution and Anticipated Future Growth

As mentioned earlier, the vehicle occupancy distribution and anticipated future growth have a significant impact on the success of an added HOV lane operation. Thus a sensitivity analysis was undertaken in which the percent of vehicles carrying 3+ persons will vary from 2% to 10% in 1% intervals (with 5% 3+ vehicles representing base conditions). The freeway demand level was also varied from 0.95 to 1.10 (in steps of 0.05) with an initial value of 1.00 representing the year 2004 freeway demand level.

The results of these sensitivity analysis investigations are summarized in Figures 5.6, 5.7, 5.8, and 5.9 with each figure representing a different freeway demand level (0.95, 1.00, 1.05, and 1.10). The rows in each figure represent measures of performances while the vertical columns represent the percent vehicles carry 3+ vehicles ranging from 2% to 10%. The results for each of the four freeway demand levels are discussed in the following four sections.

5.2.3.3 Impact of 3+ HOV Lane with 0.95 Freeway Demand Level

Figure 5.6 presents the impacts of a 3+ HOV lane with a freeway demand level of 0.95 and with a varying percent of vehicles carrying 3+ persons from 2% to 10%. Special attention will be given to six performance measures that are shown in bold type.

The reduction in total time and delay varied from 276 to 1022 passenger-hours as 3+ percentages increased from 2% to 10%. There was essentially no change in the total passenger-miles served at any 3+ vehicle percentage levels since all of the traffic that wished to travel during the peak period were able to be served during the peak period. There was a 4 mph increase in overall average speeds for HOV vehicles and a 1 to 3 mph increase in overall average speeds of non-HOV vehicles averaged over the entire peak period. Fuel consumed increased from 358 to 1778 gallons as 3+ vehicle percentages increased. Total emissions increased by 22 to 124 kilograms as 3+ vehicle percentages increased. The net increase in the fuel consumption and total emissions was due to the savings during reduced congestion periods being less than the increase due to higher freeway speeds.

5.2.3.4 Impact of 3+ HOV Lane with 1.00 Freeway Growth Level

Figure 5.7 presents the impacts of a 3+ HOV lane with a freeway demand level of 1.00 and with a varying percent of vehicles carrying 3+ persons from 2% to 10%. Special attention will be given to six measures of performance measures that are shown in bold type.

The reduction in total time and delay varied from 2770 to 5368 passenger-hours as 3+ percentages increased from 2% to 10%. There was a slight increase of 7459 to 13229 passenger-miles served since all of the traffic before implementing the HOV lane was not served during the study duration period. There was a 17mph increase in overall average speeds for HOV vehicles and a 8 to 15 mph increase in overall average speeds of non-HOV vehicles. Fuel consumed was slightly reduced (-196 gallons) at lower 3+ percentages and higher (+1556 gallons) at higher 3+ percentages. Total emissions were slightly reduced (55 kilograms) at lower 3+ percentages and slightly increased (44 kilograms) at higher 3+ percentages.

5.2.3.5 Impact of 3+ HOV Lane with 1.05 Freeway Growth Level

Figure 5.8 presents the impacts of a 3+ HOV lane with a freeway demand level of 1.05 and with a varying percent of vehicles carrying 3+ persons from 2% to 10%. Special attention will be given to six measures of performance measures that are shown in bold type.

The reduction in total time and delay savings varied from 2027 to 11297 passenger-hours as 3+ percentages increased from 2% to 10%. There was an increase in passenger-miles served varying from 17,831 to 57,058 since all of the traffic before implementing the HOV lane were not served during the study duration period. There was a 28 mph increase in overall average speeds for HOV vehicles and a 3 to 24 mph increase in overall average speeds of non-HOV vehicles. Fuel consumed was increased by 489 gallons at lower 3+ percentages and by 1305 gallons at higher 3+ percentages. Total emissions were slightly increased (2 kilograms) at lower 3+ percentages and slightly reduced (55 kilograms) at higher 3+ percentages.

5.2.3.6 Impact of 3+ HOV Lane with 1.10 Freeway Growth Level

Figure 5.9 presents the impacts of a 3+ HOV lane with a freeway demand level of 1.10 and with a varying percent of vehicles carrying 3+ persons from 2% to 10%. Special attention will be given to six measures of performance measures that are shown in bold type.

The reduction in total time and delay savings varied from 1333 to 11276 passenger-hours as 3+ vehicle percentages increased from 2% to 10%. There was an increase in passenger-miles served varying from 20,934 to 103,737 since all of the traffic before implementing the HOV lane were not served during the study duration period. There was a 32 mph increase in overall average speeds for HOV vehicles and a 1 to 18 mph increase in overall average speeds of non-HOV vehicles. Fuel consumed increased by 666 gallons at lower 3+ percentages and 2076 gallons at higher 3+

percentages. Total emissions were slightly increased by 36 kilograms at lower 3+ percentages and by 16 kilograms at higher 3+ percentages.

5.2.3.7 Overall Summary of Results on Each Measure of Performance

Sensitivity of results presented on a percentage basis for sixteen selected measures of performance is shown in Figures 5.10A, 5.10B, 5.10C, and 5.10D. Recall that the base conditions assumed that 5% of the vehicles carry 3+ persons and the growth factor was 1.00. Comments on each of the sixteen selected measures of performance are presented in the following sixteen paragraphs.

The percent change in total time and delay in passenger-hours is always reduced with the introduction of a HOV lane and varies from -2 to -36 %. The smallest reductions occur when the existing freeway is not very congested while the largest reductions occur at high percentage of 3+ vehicles and when the level of congestion is moderate. The base condition results in a 20% reduction (Figure 5.10A).

The percent change in freeway travel time in passenger-miles was never reduced with the introduction of a HOV lane and the increase varied from 0 to 9 %. Any increase in passenger-miles of travel occurred because the peak period demand was not served within the study duration period in the analysis of the before added HOV lane situation. These unserved vehicles were transferred to time periods beyond the study duration period and not included in the analysis. Therefore more people and vehicles were served within the study duration period particularly with demand growth and higher 3+ HOV percentages. The base condition results in a 1% reduction (Figure 5.10A).

The percent change in overall average HOV vehicle speeds in mph always increased with the introduction of a HOV lane and the increase varied from 7 to 94 %. The reason that the increase in HOV vehicle speeds were always the same regardless of 3+ HOV percentages was that the HOV lane was never congested and the flows in the HOV lane were significantly lower than the capacity. The higher demand growth levels investigated resulted in greater increases in HOV speeds because the speeds of HOV vehicles before the introduction of the HOV lane were very low. The base condition resulted in a 35% (17 mph) increase in HOV vehicle speeds (Figure 5.10A).

The percent change in overall average non-HOV vehicle speeds in mph always increased with the introduction of a HOV lane and the increase varied from 2 to 64%. The reason why the non-HOV speeds always increased was that the demand in the non-HOV lanes was reduced due to HOV vehicles using the HOV lane. The larger increases occurred when the 3+ HOV vehicle percentage was higher and the demand growth was moderately high. Extremely high demand growths combined with higher 3+ HOV percentages resulted in slightly lower percentage increase in non-HOV vehicle speeds due to congestion extending upstream of the freeway study section. The base condition resulted in a 26% (12 mph) increase in non-HOV vehicle speeds (Figure 5.10A).

The percent change in total fuel consumed varied from –1 to +5% with the greatest increases occurring at higher 3+ HOV percentages. This was due to higher speeds of the HOV vehicles in the HOV lane and somewhat higher speeds in some sections of the non-HOV lanes in some periods during the study duration period. While fuel consumption was reduced during congested periods, fuel consumption increased during free-flow periods of time. Also keep in mind that more people and vehicles were served with the introduction of the HOV lane. The base condition resulted in a 1% increase in fuel consumption (Figure 5.10B).

The percentage change in total emissions varied from –2 to +4%. The greatest increases occurring at higher 3+ percentages and lower demand levels. All other changes were very modest and lying between +/- 2%. The base condition resulted in a 1% decrease in vehicle emissions (Figure 5.10B).

Another set of results that is often helpful is the level of flow in the HOV lane. Low flows in the HOV lane indicate that the added HOV lane is not being effectively used and also non-HOV users particularly may be concerned about this under-utilization. Obviously high flows approaching the capacity of the HOV lane are of concern because of the poor level of service being provided to HOV users and also because of not having available capacity for future HOV growth. Too high a flow in the HOV lane was not a problem in these sensitivity investigations. Investigations at lower 3+ HOV percentages combined with lower levels of traffic demands resulted in low flows in the HOV lane. The base condition resulted in a flow level that generally did not exceed 300 to 350 vehicles per hour (Figure 5.10B).

Another set of results that is often informative is the level of freeway congestion before introducing the HOV lane and then the level of freeway congestion in the HOV and non-HOV lanes after the introduction of the HOV lane. For each cell in the eighth table of Figure 5.10 there is a code of three letters indicating the level of freeway congestion before the HOV is introduced and then the level of congestion in the HOV lane and the non-HOV lane. The following letters are used to indicate the level of congestion: no congestion (N), light congestion (L), moderate congestion (M), and heavy congestion (H). The designation of light, moderate, and heavy congestion is determined qualitatively for comparison purposes. Note that there is never any congestion in the HOV lane and that the non-HOV lane users encounter less congestion after the introduction of the HOV lane. The base condition resulted in moderate congestion before the introduction of the HOV and no congestion in the HOV lane and little congestion in the non-HOV lanes (Figure 5.10B).

The four tables contained in Figure 5.10C provide total quantities expended in fuel consumption, vehicle emissions, passenger time, and passenger travel. These total quantities can be misleading in assessing the implementation of HOV lanes. For example, the total passenger-miles traveled within the study section and study duration period varied between investigations. Hence total fuel consumption, vehicle emissions, and passenger-hours would be expected to vary due to different levels of total passenger-miles of travel as well as due to the appropriateness of the HOV lane design. The total quantities shown in Figure 5.10C were used to create the first three tables contained in Figure 5.10D.

Average fuel consumption rates (passenger-miles per gallon) are displayed in the first table of Figure 5.10D. The average fuel consumption under the base conditions of 5% HOV vehicles and growth factor of 1.00 was 25.6 pass-miles/gal. The rates were primarily affected by % HOV vehicle levels. Higher rates occurred at higher % HOV vehicle levels. Any increase in % HOV vehicle levels combined with increased demand growth above the base conditions resulted in improved average fuel consumption rates.

Average vehicle emission rates (passenger-miles per kilogram) are displayed in the second table of Figure 5.10D. The average vehicle emission rate under the base conditions was 293 pass-miles/kg. The highest rates were observed at mid-range growth factors and higher % HOV vehicle levels. Any increase in % HOV vehicle levels combined with increased demand growth above the base conditions resulted in improved average vehicle emission rates.

Average vehicle speeds (miles per hour) are displayed in the third table of Figure 5.10D. Another way of looking at this rate is in terms of passenger-miles traveled per hour of time. Average vehicle speeds are primarily affected by the demand growth level with increases in traffic demands leading to reduced average speeds. Increases in % HOV vehicle levels lead toward higher average speeds.

The final table in Figure 5.10D displays the differential average speeds between the HOV lane and the non-HOV lanes for various traffic demand levels and percentage of 3+ HOV vehicles. The differential average speed is approximately only 4 mph under the base case of 5% HOV vehicle level with a demand growth of 1.00. Increase in % HOV vehicle levels combined increases in traffic demand level leads to greater differential speeds.

		BEFORE IMPLEMENTATION			AFTER IMPLEMENTATION			DIFFERENCES			
		FREEWAY	ALT.RTE	TOTAL	FREEWAY	ALT.RTE	TOTAL	FREEWAY	ART.RTE	TOTAL	PER.CHANGE
TRAVEL TIME	VEH-HR	16642.	0.	16642.	13375.	0.	13375.	-3266.	0.	-3266.	-19.63
	PASS-HR	20968.	0.	20968.	16766.	0.	16766.	-4202.	0.	-4202.	-20.04
TRAVEL DISTANCE	VEH-MI	798987.	0.	798987.	808474.	0.	808474.	9487.	0.	9487.	1.19
	PASS-MI	1006723.	0.	1006723.	1018660.	0.	1018660.	11937.	0.	11937.	1.19
AVG.SPD.	MPH.	48.15	0.00	48.15	60.81	0.00	60.81	12.65	0.00	12.65	26.27
GASOLINE	GALLONS	39219.	0.	39219.	39762.	0.	39762.	543.	0.	543.	1.38
HYD-CARB	KILOGRAMS	246.	0.	246.	239.	0.	239.	-7.	0.	-7.	-2.91
CARB-MON	KILOGRAMS	2968.	0.	2968.	2950.	0.	2950.	-17.	0.	-17.	-0.58
NIT.-OX.	KILOGRAMS	284.	0.	284.	287.	0.	287.	2.	0.	2.	0.83
ALL-EMIS	KILOGRAMS	3498.	0.	3498.	3476.	0.	3476.	-22.	0.	-22.	-0.63

DIFFERENTIAL EFFECTS TABLE AFTER (DAY+1)

Figure 5.5 I-580 Freeway Performance Without Added HOV Lane

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE (GF=0.95)									I580EP-FN3	
MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 0.95 3+ HOV = 2%	GF = 0.95 3+ HOV = 3%	GF = 0.95 3+ HOV = 4%	GF = 0.95 3+ HOV = 5%	GF = 0.95 3+ HOV = 6%	GF = 0.95 3+ HOV = 7%	GF = 0.95 3+ HOV = 8%	GF = 0.95 3+ HOV = 9%	GF = 0.95 3+ HOV = 10%
FREEWAY	W/O HOV LANE	14267	14800	15333	15993	16399	16679	17085	17618	18024
TRAVEL TIME	WITH HOV LANE	13991	14404	14831	15379	15684	15881	16215	16662	17002
PASS-HRS	DIFFERENCE	-276	-396	-502	-614	-715	-798	-870	-956	-1022
	% DIFFERENCE	-1.9	-2.7	-3.3	-3.8	-4.4	-4.8	-5.1	-5.4	-5.7
RAMP	W/O HOV LANE	28	29	30	31	32	33	33	34	35
DELAY	WITH HOV LANE	28	30	31	32	36	33	34	35	36
PASS-HRS	DIFFERENCE	0	1	1	1	4	0	1	1	1
	% DIFFERENCE	0.0	3.4	3.3	3.2	12.5	0.0	3.0	2.9	2.9
TOTAL	W/O HOV LANE	14295	14829	15363	16024	16431	16711	17118	17652	18059
TIME & DELAY	WITH HOV LANE	14019	14434	14862	15411	15720	15914	16249	16697	17038
PASS-HRS	DIFFERENCE	**-276**	**-395**	**-501**	**-613**	**-711**	**-797**	**-869**	**-955**	**-1021**
	% DIFFERENCE	-1.9	-2.7	-3.3	-3.8	-4.3	-4.8	-5.1	-5.4	-5.7
FREEWAY	W/O HOV LANE	864226	896519	928812	968795	993399	1010314	1034919	1067212	1091816
TRAVEL	WITH HOV LANE	864200	896373	928584	968540	993136	1010047	1034644	1066929	1091527
PASS-MILES	DIFFERENCE	**-26**	**-146**	**-228**	**-255**	**-263**	**-267**	**-275**	**-283**	**-289**
	% DIFFERENCE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FREEWAY	W/O HOV LANE	60.6	60.6	60.6	60.6	60.6	60.6	60.6	60.6	60.6
AVG SPEED	HOV LANE	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0
MPH	MIXED-FLOW	61.6	62.0	62.3	62.7	63.0	63.3	63.5	63.8	64.0
	HOV DIFF	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**
	NON-HOV DIFF	**1.0**	**1.4**	**1.7**	**2.1**	**2.4**	**2.7**	**2.9**	**3.2**	**3.4**
	% DIFF HOV	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3
	%DIFF NON-HOV	1.7	2.3	2.8	3.5	4.0	4.5	4.8	5.3	5.6
TOTAL FUEL	W/O HOV LANE	37803	37803	37803	37803	37803	37803	37803	37803	37803
CONSUMED	WITH HOV LANE	38161	38344	38533	38760	38979	39180	39313	39476	39581
GALLONS	DIFFERENCE	**358**	**541**	**730**	**957**	**1176**	**1377**	**1510**	**1673**	**1778**
	% DIFFERENCE	0.9	1.4	1.9	2.5	3.1	3.6	4.0	4.4	4.7
EMFAC2002	W/O HOV LANE	226	226	226	226	226	226	226	226	226
HC EMISSIONS	WITH HOV LANE	229	231	232	234	236	238	239	241	242
KILOGRAMS	DIFFERENCE	3	5	6	8	10	12	13	15	16
	% DIFFERENCE	1.3	2.2	2.7	3.5	4.4	5.3	5.8	6.6	7.1
EMFAC2002	W/O HOV LANE	2797	2797	2797	2797	2797	2797	2797	2797	2797
CO EMISSIONS	WITH HOV LANE	2814	2824	2834	2847	2859	2871	2879	2889	2897
KILOGRAMS	DIFFERENCE	17	27	37	50	62	74	82	92	100
	% DIFFERENCE	0.6	1.0	1.3	1.8	2.2	2.6	2.9	3.3	3.6
EMFAC2002	W/O HOV LANE	273	273	273	273	273	273	273	273	273
NO EMISSIONS	WITH HOV LANE	275	276	277	278	279	280	280	281	281
KILOGRAMS	DIFFERENCE	2	3	4	5	6	7	7	8	8
	% DIFFERENCE	0.7	1.1	1.5	1.8	2.2	2.6	2.6	2.9	2.9
EMFAC2002	W/O HOV LANE	3296	3296	3296	3296	3296	3296	3296	3296	3296
TOTAL EMISSION	WITH HOV LANE	3318	3331	3343	3359	3374	3389	3398	3411	3420
KILOGRAMS	DIFFERENCE	**22**	**35**	**47**	**63**	**78**	**93**	**102**	**115**	**124**
	% DIFFERENCE	0.7	1.1	1.4	1.9	2.4	2.8	3.1	3.5	3.8

Figure 5.6 Effect of Demand Growth and 3+ Vehicle Percentages o Performance of Full Length No Barrier HOV Lane (GF=0.95)

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE (GF=1.00) I580EP-FN3

MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 1.00 3+ HOV = 2%	GF = 1.00 3+ HOV = 3%	GF = 1.00 3+ HOV = 4%	GF = 1.00 3+ HOV = 5%	GF = 1.00 3+ HOV = 6%	GF = 1.00 3+ HOV = 7%	GF = 1.00 3+ HOV = 8%	GF = 1.00 3+ HOV = 9%	GF = 1.00 3+ HOV = 10%
FREEWAY	W/O HOV LANE	18650	19346	20043	20906	21437	21802	22333	23030	23561
TRAVEL TIME	WITH HOV LANE	15861	16076	16226	16666	16929	17093	17395	17836	18152
PASS-HRS	DIFFERENCE	-2789	-3270	-3817	-4240	-4508	-4709	-4938	-5194	-5409
	% DIFFERENCE	-15.0	-16.9	-19.0	-20.3	-21.0	-21.6	-22.1	-22.6	-23.0
RAMP	W/O HOV LANE	56	58	60	62	64	65	67	69	70
DELAY	WITH HOV LANE	74	89	99	100	102	103	105	108	111
PASS-HRS	DIFFERENCE	18	31	39	38	38	38	38	39	41
	% DIFFERENCE	32.1	53.4	65.0	61.3	59.4	58.5	56.7	56.5	58.6
TOTAL	W/O HOV LANE	18705	19404	20103	20968	21501	21867	22400	23098	23631
TIME & DELAY	WITH HOV LANE	15935	16165	16325	16766	17031	17196	17500	17944	18263
PASS-HRS	DIFFERENCE	**-2770**	**-3239**	**-3778**	**-4202**	**-4470**	**-4671**	**-4900**	**-5154**	**-5368**
	% DIFFERENCE	-14.8	-16.7	-18.8	-20.0	-20.8	-21.4	-21.9	-22.3	-22.7
FREEWAY	W/O HOV LANE	898061	931619	965176	1006723	1032291	1049869	1075437	1108994	1134562
TRAVEL	WITH HOV LANE	905520	943182	976789	1018660	1044642	1062307	1088062	1121939	1147791
PASS-MILES	DIFFERENCE	**7459**	**11563**	**11613**	**11937**	**12351**	**12438**	**12625**	**12945**	**13229**
	% DIFFERENCE	0.8	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
FREEWAY	W/O HOV LANE	48.2	48.2	48.2	48.2	48.2	48.2	48.2	48.2	48.2
AVG SPEED	HOV LANE	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0
MPH	MIXED-FLOW	56.7	58.2	59.7	60.6	61.2	61.6	62.0	62.4	62.8
	HOV DIFF	**16.8**	**16.8**	**16.8**	**16.8**	**16.8**	**16.8**	**16.8**	**16.8**	**16.8**
	NON-HOV DIFF	**8.5**	**10.0**	**11.5**	**12.4**	**13.0**	**13.4**	**13.8**	**14.2**	**14.6**
	% DIFF HOV	34.9	34.9	34.9	34.9	34.9	34.9	34.9	34.9	34.9
	%DIFF NON-HOV	17.6	20.7	23.9	25.7	27.0	27.8	28.6	29.5	30.3
TOTAL FUEL	W/O HOV LANE	39219	39219	39219	39219	39219	39219	39219	39219	39219
CONSUMED	WITH HOV LANE	39023	39267	39488	39762	39946	40129	40321	40545	40775
GALLONS	DIFFERENCE	**-196**	**48**	**269**	**543**	**727**	**910**	**1102**	**1326**	**1556**
	% DIFFERENCE	-0.5	0.1	0.7	1.4	1.9	2.3	2.8	3.4	4.0
EMFAC2002	W/O HOV LANE	246	246	246	246	246	246	246	246	246
HC EMISSIONS	WITH HOV LANE	235	235	237	239	240	242	244	246	248
KILOGRAMS	DIFFERENCE	-11	-11	-9	-7	-6	-4	-2	0	2
	% DIFFERENCE	-4.5	-4.5	-3.7	-2.8	-2.4	-1.6	-0.8	0.0	0.8
EMFAC2002	W/O HOV LANE	2968	2968	2968	2968	2968	2968	2968	2968	2968
CO EMISSIONS	WITH HOV LANE	2925	2936	2940	2950	2959	2968	2979	2991	3003
KILOGRAMS	DIFFERENCE	-43	-32	-28	-18	-9	0	11	23	35
	% DIFFERENCE	-1.4	-1.1	-0.9	-0.6	-0.3	0.0	0.4	0.8	1.2
EMFAC2002	W/O HOV LANE	284	284	284	284	284	284	284	284	284
NO EMISSIONS	WITH HOV LANE	283	284	285	287	287	288	289	290	291
KILOGRAMS	DIFFERENCE	-1	0	1	3	3	4	5	6	7
	% DIFFERENCE	-0.4	0.0	0.4	1.1	1.1	1.4	1.8	2.1	2.5
EMFAC2002	W/O HOV LANE	3498	3498	3498	3498	3498	3498	3498	3498	3498
TOTAL EMISSION	WITH HOV LANE	3443	3455	3462	3476	3486	3498	3512	3527	3542
KILOGRAMS	DIFFERENCE	**-55**	**-43**	**-36**	**-22**	**-12**	**0**	**14**	**29**	**44**
	% DIFFERENCE	-1.6	-1.2	-1.0	-0.6	-0.3	0.0	0.4	0.8	1.3

Figure 5.7 Effect of Demand Growth and 3+ Vehicle Percentages on Performance of Full Length No Barrier HOV Lane (GF=1.0)

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE (GF=1.05) I580EP-FN3

MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 1.05 3+ HOV = 2%	GF = 1.05 3+ HOV = 3%	GF = 1.05 3+ HOV = 4%	GF = 1.05 3+ HOV = 5%	GF = 1.05 3+ HOV = 6%	GF = 1.05 3+ HOV = 7%	GF = 1.05 3+ HOV = 8%	GF = 1.05 3+ HOV = 9%	GF = 1.05 3+ HOV = 10%
FREEWAY	W/O HOV LANE	24407	25319	26231	27360	28055	28532	29227	30139	30834
TRAVEL TIME	WITH HOV LANE	22535	21830	21310	20908	20162	19357	19028	19291	19505
PASS-HRS	DIFFERENCE	-1872	-3489	-4921	-6452	-7893	-9175	-10199	-10848	-11329
	% DIFFERENCE	-7.7	-13.8	-18.8	-23.6	-28.1	-32.2	-34.9	-36.0	-36.7
RAMP	W/O HOV LANE	267	277	287	299	307	312	319	329	337
DELAY	WITH HOV LANE	111	135	160	193	238	302	352	363	369
PASS-HRS	DIFFERENCE	-156	-142	-127	-106	-69	-10	33	34	32
	% DIFFERENCE	-58.4	-51.3	-44.3	-35.5	-22.5	-3.2	10.3	10.3	9.5
TOTAL	W/O HOV LANE	24673	25595	26517	27659	28361	28844	29546	30468	31171
TIME & DELAY	WITH HOV LANE	22646	21965	21470	21101	20400	19659	19380	19654	19874
PASS-HRS	DIFFERENCE	**-2027**	**-3630**	**-5047**	**-6558**	**-7961**	**-9185**	**-10166**	**-10814**	**-11297**
	% DIFFERENCE	-8.2	-14.2	-19.0	-23.7	-28.1	-31.8	-34.4	-35.5	-36.2
FREEWAY	W/O HOV LANE	908148	942083	976017	1018031	1043886	1061661	1087516	1121450	1147305
TRAVEL	WITH HOV LANE	925979	968040	1009690	1059508	1092315	1114477	1141895	1177265	1204363
PASS-MILES	DIFFERENCE	**17831**	**25957**	**33673**	**41477**	**48429**	**52816**	**54379**	**55815**	**57058**
	% DIFFERENCE	2.0	2.8	3.5	4.1	4.6	5.0	5.0	5.0	5.0
FREEWAY	W/O HOV LANE	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2
AVG SPEED	HOV LANE	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0
MPH	MIXED-FLOW	40.2	43.2	46.0	49.2	52.7	56.3	59.0	60.1	60.9
	HOV DIFF	**27.8**	**27.8**	**27.8**	**27.8**	**27.8**	**27.8**	**27.8**	**27.8**	**27.8**
	NON-HOV DIFF	**3.0**	**6.0**	**8.8**	**12.0**	**15.5**	**19.1**	**21.8**	**22.9**	**23.7**
	% DIFF HOV	74.7	74.7	74.7	74.7	74.7	74.7	74.7	74.7	74.7
	%DIFF NON-HOV	8.1	16.1	23.7	32.3	41.7	51.3	58.6	61.6	63.7
TOTAL FUEL	W/O HOV LANE	40530	40530	40530	40530	40530	40530	40530	40530	40530
CONSUMED	WITH HOV LANE	41019	41139	41142	41148	41154	41169	41352	41604	41835
GALLONS	DIFFERENCE	**489**	**609**	**612**	**618**	**624**	**639**	**822**	**1074**	**1305**
	% DIFFERENCE	1.2	1.5	1.5	1.5	1.5	1.6	2.0	2.6	3.2
EMFAC2002	W/O HOV LANE	273	273	273	273	273	273	273	273	273
HC EMISSIONS	WITH HOV LANE	270	266	261	257	253	249	249	251	253
KILOGRAMS	DIFFERENCE	-3	-7	-12	-16	-20	-24	-24	-22	-20
	% DIFFERENCE	-1.1	-2.6	-4.4	-5.9	-7.3	-8.8	-8.8	-8.1	-7.3
EMFAC2002	W/O HOV LANE	3154	3154	3154	3154	3154	3154	3154	3154	3154
CO EMISSIONS	WITH HOV LANE	3156	3139	3128	3118	3108	3096	3094	3102	3112
KILOGRAMS	DIFFERENCE	2	-15	-26	-36	-46	-58	-60	-52	-42
	% DIFFERENCE	0.1	-0.5	-0.8	-1.1	-1.5	-1.8	-1.9	-1.6	-1.3
EMFAC2002	W/O HOV LANE	293	293	293	293	293	293	293	293	293
NO EMISSIONS	WITH HOV LANE	296	297	297	297	298	298	298	299	300
KILOGRAMS	DIFFERENCE	3	4	4	4	5	5	5	6	7
	% DIFFERENCE	1.0	1.4	1.4	1.4	1.7	1.7	1.7	2.0	2.4
EMFAC2002	W/O HOV LANE	3720	3720	3720	3720	3720	3720	3720	3720	3720
TOTAL EMISSION	WITH HOV LANE	3722	3702	3686	3672	3659	3643	3641	3652	3665
KILOGRAMS	DIFFERENCE	**2**	**-18**	**-34**	**-48**	**-61**	**-77**	**-79**	**-68**	**-55**
	% DIFFERENCE	0.1	-0.5	-0.9	-1.3	-1.6	-2.1	-2.1	-1.8	-1.5

Figure 5.8 Effect of Demand Growth and 3+ Vehicle Percentages on Performance of Full Length No Barrier HOV Lane (GF=1.05)

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE (GF=1.10)									I580EP-FN3	
MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 1.10 3+ HOV = 2%	GF = 1.10 3+ HOV = 3%	GF = 1.10 3+ HOV = 4%	GF = 1.10 3+ HOV = 5%	GF = 1.10 3+ HOV = 6%	GF = 1.10 3+ HOV = 7%	GF = 1.10 3+ HOV = 8%	GF = 1.10 3+ HOV = 9%	GF = 1.10 3+ HOV = 10%
FREEWAY	W/O HOV LANE	27192	28208	29224	30482	31256	31788	32562	33578	34352
TRAVEL TIME	WITH HOV LANE	26041	26382	26596	26902	26596	24809	24657	23965	23107
PASS-HRS	DIFFERENCE	-1151	-1826	-2628	-3580	-4660	-6979	-7905	-9613	-11245
	% DIFFERENCE	-4.2	-6.5	-9.0	-11.7	-14.9	-22.0	-24.3	-28.6	-32.7
RAMP	W/O HOV LANE	844	875	907	946	970	986	1010	1042	1066
DELAY	WITH HOV LANE	661	614	563	587	565	611	736	880	1035
PASS-HRS	DIFFERENCE	-183	-261	-344	-359	-405	-375	-274	-162	-31
	% DIFFERENCE	-21.7	-29.8	-37.9	-37.9	-41.8	-38.0	-27.1	-15.5	-2.9
TOTAL	W/O HOV LANE	28035	29083	30130	31427	32226	32774	33572	34620	35418
TIME & DELAY	WITH HOV LANE	26702	26996	27159	27489	27161	25420	25393	24845	24142
PASS-HRS	DIFFERENCE	**-1333**	**-2087**	**-2971**	**-3938**	**-5065**	**-7354**	**-8179**	**-9775**	**-11276**
	% DIFFERENCE	-4.8	-7.2	-9.9	-12.5	-15.7	-22.4	-24.4	-28.2	-31.8
FREEWAY	W/O HOV LANE	911595	945658	979722	1021895	1047848	1065691	1091644	1125707	1151660
TRAVEL	WITH HOV LANE	932529	977339	1022573	1076897	1113845	1138968	1176855	1220632	1255397
PASS-MILES	DIFFERENCE	**20934**	**31681**	**42851**	**55002**	**65997**	**73277**	**85211**	**94925**	**103737**
	% DIFFERENCE	2.3	3.4	4.4	5.4	6.3	6.9	7.8	8.4	9.0
FREEWAY	W/O HOV LANE	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5
AVG SPEED	HOV LANE	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0
MPH	MIXED-FLOW	34.6	35.7	36.7	38.0	39.5	43.4	45.1	48.3	52.0
	HOV DIFF	**31.5**	**31.5**	**31.5**	**31.5**	**31.5**	**31.5**	**31.5**	**31.5**	**31.5**
	NON-HOV DIFF	**1.1**	**2.2**	**3.2**	**4.5**	**6.0**	**9.9**	**11.6**	**14.8**	**18.5**
	% DIFF HOV	94.0	94.0	94.0	94.0	94.0	94.0	94.0	94.0	94.0
	%DIFF NON-HOV	3.3	6.6	9.6	13.4	17.9	29.6	34.6	44.2	55.2
TOTAL FUEL	W/O HOV LANE	41150	41150	41150	41150	41150	41150	41150	41150	41150
CONSUMED	WITH HOV LANE	41816	42087	42341	42621	42888	43016	43162	43201	43226
GALLONS	DIFFERENCE	**666**	**937**	**1191**	**1471**	**1738**	**1866**	**2012**	**2051**	**2076**
	% DIFFERENCE	1.6	2.3	2.9	3.6	4.2	4.5	4.9	5.0	5.0
EMFAC2002	W/O HOV LANE	287	287	287	287	287	287	287	287	287
HC EMISSIONS	WITH HOV LANE	288	288	287	286	285	279	277	273	269
KILOGRAMS	DIFFERENCE	1	1	0	-1	-2	-8	-10	-14	-18
	% DIFFERENCE	0.3	0.3	0.0	-0.3	-0.7	-2.8	-3.5	-4.9	-6.3
EMFAC2002	W/O HOV LANE	3260	3260	3260	3260	3260	3260	3260	3260	3260
CO EMISSIONS	WITH HOV LANE	3290	3300	3306	3313	3316	3280	3295	3286	3279
KILOGRAMS	DIFFERENCE	30	40	46	53	56	20	35	26	19
	% DIFFERENCE	0.9	1.2	1.4	1.6	1.7	0.6	1.1	0.8	0.6
EMFAC2002	W/O HOV LANE	297	297	297	297	297	297	297	297	297
NO EMISSIONS	WITH HOV LANE	302	303	305	307	309	310	311	311	312
KILOGRAMS	DIFFERENCE	5	6	8	10	12	13	14	14	15
	% DIFFERENCE	1.7	2.0	2.7	3.4	4.0	4.4	4.7	4.7	5.1
EMFAC2002	W/O HOV LANE	3844	3844	3844	3844	3844	3844	3844	3844	3844
TOTAL EMISSION	WITH HOV LANE	3880	3891	3898	3906	3910	3869	3883	3870	3860
KILOGRAMS	DIFFERENCE	**36**	**47**	**54**	**62**	**66**	**25**	**39**	**26**	**16**
	% DIFFERENCE	0.9	1.2	1.4	1.6	1.7	0.7	1.0	0.7	0.4

Figure 5.9 Effect of Demand Growth and 3+ Vehicle Percentages of Performance of Full Length No Barrier HOV Lane (GF=1.10)

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3

MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
TOTAL	0.95	**-1.9**	**-2.7**	**-3.3**	**-3.8**	**-4.3**	**-4.8**	**-5.1**	**-5.4**	**-5.7**
TIME & DELAY	1.00	**-14.8**	**-16.7**	**-18.8**	**-20.0**	**-20.8**	**-21.4**	**-21.9**	**-22.3**	**-22.7**
PASS-HRS	1.05	**-8.2**	**-14.2**	**-19.0**	**-23.7**	**-28.1**	**-31.8**	**-34.4**	**-35.5**	**-36.2**
(% Change)	1.10	**-4.8**	**-7.2**	**-9.9**	**-12.5**	**-15.7**	**-22.4**	**-24.4**	**-28.2**	**-31.8**

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3

MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
FREEWAY	0.95	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
TRAVEL	1.00	**0.8**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
PASS-MILES	1.05	**2.0**	**2.8**	**3.5**	**4.1**	**4.6**	**5.0**	**5.0**	**5.0**	**5.0**
(% Change)	1.10	**2.3**	**3.4**	**4.4**	**5.4**	**6.3**	**6.9**	**7.8**	**8.4**	**9.0**

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3

MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
HOV VEHICLES	0.95	**7.3**	**7.3**	**7.3**	**7.3**	**7.3**	**7.3**	**7.3**	**7.3**	**7.3**
AVG SPEED	1.00	**34.9**	**34.9**	**34.9**	**34.9**	**34.9**	**34.9**	**34.9**	**34.9**	**34.9**
MPH	1.05	**74.7**	**74.7**	**74.7**	**74.7**	**74.7**	**74.7**	**74.7**	**74.7**	**74.7**
(% Change)	1.10	**94.0**	**94.0**	**94.0**	**94.0**	**94.0**	**94.0**	**94.0**	**94.0**	**94.0**

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3

MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
NON-HOV	0.95	**1.7**	**2.3**	**2.8**	**3.5**	**4.0**	**4.5**	**4.8**	**5.3**	**5.6**
VEHICLE	1.00	**17.6**	**20.7**	**23.9**	**25.7**	**27.0**	**27.8**	**28.6**	**29.5**	**30.3**
AVG SPEED	1.05	**8.1**	**16.1**	**23.7**	**32.3**	**41.7**	**51.3**	**58.6**	**61.6**	**63.7**
MPH (% Change)	1.10	**3.3**	**6.6**	**9.6**	**13.4**	**17.9**	**29.6**	**34.6**	**44.2**	**55.2**

Figure 5.10A Summary Effects of Demand Growth Level and 3+Vehicle Percentages on Performance of Full Length No Barrier HOV Lane

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3

MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
TOTAL FUEL	0.95	**0.9**	**1.4**	**1.9**	**2.5**	**3.1**	**3.6**	**4.0**	**4.4**	**4.7**
CONSUMED	1.00	**-0.5**	**0.1**	**0.7**	**1.4**	**1.9**	**2.3**	**2.8**	**3.4**	**4.0**
GALLONS	1.05	**1.2**	**1.5**	**1.5**	**1.5**	**1.5**	**1.6**	**2.0**	**2.6**	**3.2**
(% Change)	1.10	**1.6**	**2.3**	**2.9**	**3.6**	**4.2**	**4.5**	**4.9**	**5.0**	**5.0**

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3

MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
EMFAC2002	0.95	**0.7**	**1.1**	**1.4**	**1.9**	**2.4**	**2.8**	**3.1**	**3.5**	**3.8**
TOTAL EMISSION	1.00	**-1.6**	**-1.2**	**-1.0**	**-0.6**	**-0.3**	**0.0**	**0.4**	**0.8**	**1.3**
KILOGRAMS	1.05	**0.1**	**-0.5**	**-0.9**	**-1.3**	**-1.6**	**-2.1**	**-2.1**	**-1.8**	**-1.5**
(% Change)	1.10	**0.9**	**1.2**	**1.4**	**1.6**	**1.7**	**0.7**	**1.0**	**0.7**	**0.4**

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3

MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
FLOW LEVEL	0.95	**50-100**	**100-150**	**200-250**	**300-350**	**350-400**	**450-500**	**500-550**	**550-600**	**600-650**
IN HOV LANE	1.00	**50-100**	**100-150**	**200-250**	**300-350**	**350-400**	**450-500**	**500-550**	**550-600**	**600-650**
(VEHS/HOUR)	1.05	**100-150**	**150-200**	**250-300**	**350-400**	**400-450**	**500-550**	**550-600**	**600-650**	**650-700**
	1.10	**100-150**	**150-200**	**250-300**	**350-400**	**400-450**	**500-550**	**550-600**	**600-650**	**650-700**

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3

MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
LEVEL OF	0.95	**L/N/L**	**L/N/L**	**L/N/N**	**L/N/N**	**L/N/N**	**L/N/N**	**L/N/N**	**L/N/N**	**L/N/N**
FREEWAY	1.00	**M/N/L**	**M/N/L**	**M/N/L**	**M/N/L**	**M/N/L**	**M/N/N**	**M/N/N**	**M/N/N**	**M/N/N**
CONGESTION	1.05	**H/N/H**	**H/N/M**	**H/N/M**	**H/N/M**	**H/N/M**	**H/N/M**	**H/N/M**	**H/N/M**	**H/N/M**
	1.10	**H/N/H**	**H/N/H**	**H/N/H**	**H/N/H**	**H/N/H**	**H/N/M**	**H/N/M**	**H/N/M**	**H/N/M**

X/Y/Z = LEVEL OF FREEWAY CONGESTION : BEFORE/HOV LANE/NON-HOV LANES N= NONE L=LIGHT M=MODERATE H=HEAVY

Figure 5.10B Summary Effects of Demand Growth Level and 3+ Vehicle Percentages on Performance of Full Length No Barrier HOV Lane

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3										
MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
TOTAL FUEL	0.95	**38161**	**38344**	**38533**	**38760**	**38979**	**39180**	**39313**	**39476**	**39581**
CONSUMED	1.00	**39023**	**39267**	**39488**	**39762**	**39946**	**40129**	**40321**	**40545**	**40775**
(GALLONS)	1.05	**41019**	**41139**	**41142**	**41148**	**41154**	**41169**	**41352**	**41604**	**41835**
	1.10	**41816**	**42087**	**42341**	**42621**	**42888**	**43016**	**43162**	**43201**	**43226**

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3										
MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
EMFAC2002	0.95	**3318**	**3331**	**3343**	**3359**	**3374**	**3389**	**3398**	**3411**	**3420**
TOTAL EMISSION	1.00	**3443**	**3455**	**3462**	**3476**	**3486**	**3498**	**3512**	**3527**	**3542**
(KILOGRAMS)	1.05	**3722**	**3702**	**3686**	**3672**	**3659**	**3643**	**3641**	**3652**	**3665**
	1.10	**3880**	**3891**	**3898**	**3906**	**3910**	**3869**	**3883**	**3870**	**3860**

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3										
MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
TOTAL TIME	0.95	**14019**	**14434**	**14862**	**15411**	**15720**	**15914**	**16249**	**16697**	**17038**
AND DELAY	1.00	**15935**	**16165**	**16325**	**16766**	**17031**	**17196**	**17500**	**17944**	**18263**
(PASS-HRS)	1.05	*** 22646**	*** 21965**	*** 21470**	*** 21101**	*** 20400**	*** 19659**	**19380**	**19654**	**19874**
	1.10	*** 26702**	*** 26996**	*** 27159**	*** 27489**	*** 27161**	*** 25420**	*** 25393**	*** 24845**	*** 24142**

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3										
MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
TOTAL TRAVEL	0.95	**864200**	**896373**	**928584**	**968540**	**993136**	**1010047**	**1034644**	**1066929**	**1091527**
DISTANCE	1.00	**905520**	**943182**	**976789**	**1018660**	**1044642**	**1062307**	**1088062**	**1121939**	**1147791**
(PASS-MILES)	1.05	**925979**	**968040**	**1009690**	**1059508**	**1092315**	**1114477**	**1141895**	**1177265**	**1204363**
	1.10	**932529**	**977339**	**1022573**	**1076897**	**1113845**	**1138968**	**1176855**	**1220632**	**1255397**

* Congestion extends beyond the last time slice and/or upstream of the first subsection causing the total time and delay to be underestimated.

Figure 5.10C Summary Effects of Demand Growth Level and 3+ Vehicle Percentages on Performance of Full Length No Barrier HOV Lane

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3

MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
AVERAGE	0.95	**22.6**	**23.4**	**24.1**	**25.0**	**25.5**	**25.8**	**26.3**	**27.0**	**27.6**
FUEL	1.00	**23.2**	**24.0**	**24.7**	**25.6**	**26.2**	**26.5**	**27.0**	**27.7**	**28.1**
CONSUMPTION	1.05	**22.6**	**23.5**	**24.5**	**25.7**	**26.5**	**27.1**	**27.6**	**28.3**	**28.8**
(Pass-Miles/Gal)	1.10	**22.3**	**23.2**	**24.2**	**25.3**	**26.0**	**26.5**	**27.3**	**28.3**	**29.0**

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3

MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
AVERAGE	0.95	**260**	**269**	**278**	**288**	**294**	**298**	**304**	**313**	**319**
VEHICLE	1.00	**263**	**273**	**282**	**293**	**300**	**304**	**310**	**318**	**324**
EMISSIONS	1.05	**249**	**261**	**274**	**289**	**299**	**306**	**314**	**322**	**329**
(Pass-Miles/Kg)	1.10	**240**	**251**	**262**	**276**	**285**	**294**	**303**	**315**	**325**

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3

MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
AVERAGE	0.95	**61.6**	**62.1**	**62.5**	**62.8**	**63.2**	**63.5**	**63.7**	**63.9**	**64.1**
VEHICLE	1.00	**56.8**	**58.3**	**59.8**	**60.8**	**61.3**	**61.8**	**62.2**	**62.5**	**62.8**
SPEEDS	1.05	**40.9**	**44.1**	**47.0**	**50.2**	**53.5**	**56.7**	**58.9**	**59.9**	**60.6**
(mph)	1.10	**34.9**	**36.2**	**37.7**	**39.2**	**41.0**	**44.8**	**46.3**	**49.1**	**52.0**

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE I580EP-FN3

MEASURE OF PERFORMANCE	GROWTH FACTOR	3+ HOV = 2%	3+ HOV = 3%	3+ HOV = 4%	3+ HOV = 5%	3+ HOV = 6%	3+ HOV = 7%	3+ HOV = 8%	3+ HOV = 9%	3+ HOV = 10%
HOV SPEED	0.95	**3.4**	**3.0**	**2.7**	**2.3**	**2.0**	**1.7**	**1.5**	**1.2**	**1.0**
MINUS	1.00	**8.3**	**6.8**	**5.3**	**4.4**	**3.8**	**3.4**	**3.0**	**2.6**	**2.2**
NON HOV SPEED	1.05	**24.8**	**21.8**	**19.0**	**15.8**	**12.3**	**8.7**	**6.0**	**4.9**	**4.1**
(mph)	1.10	**30.4**	**29.3**	**28.3**	**27.0**	**25.5**	**21.6**	**19.9**	**16.7**	**13.0**

Figure 5.10D Summary Effects of Demand Growth Level and 3+ Vehicles Percentages on Performance of Full Length No Barrier HOV Lane

5.2.4 INVESTIGATIONS OF ADDED HOV LANE FOR 2+ VEHICLES

As discussed in the previous Sections 5.2.2 and 5.2.3, the investigations of an added HOV lane were initially assumed to be:

- Single added HOV lane
- HOV cut-off limit of 3+
- HOV lane over the entire study section
- Peak period operations only
- No HOV barrier
- Typical vehicle occupancy distribution
- 2004 freeway demand level

The results of the 3+ HOV lane indicated that the hourly flows varied from 50-100 vehicles per hour to 650-700 vehicles per hour during the peak periods. This indicated that the HOV lane volume/capacity ratio varied from below 10% to a high of almost 50%. In order to obtain greater utilization of the HOV lane, a second set of investigations were undertaken in which the only change in the set of HOV design parameters was to use a HOV cut-off limit of 2+ vehicles instead of a HOV cut-off limit of 3+.

The percent of vehicles carrying 2+ persons was varied from 10% to 30% with an initial value of 20%. The freeway demand level was varied from 0.95 to 1.10 with an initial value of 1.00 representing the year 2004 freeway demand level.

5.2.4.1 Effect of Adding the HOV Lane

A summary table showing the differential effects of adding the HOV lane to this study section is shown in Figure 5.11. The measures of effectiveness are shown in the first two columns; the performance measures before the implementation of the HOV lane are shown in the next three columns; the performance measures after the implementation of the HOV lane are shown in the next three columns; and the differences in performance measures are shown in the final four columns. Note that this investigation is limited to the freeway only and does not include the modeling of the arterial routes.

The adding of the HOV lane has reduced total passenger-hours by 24%, increased passenger-miles served by over 1%, increased average overall freeway speed by 34%, increased fuel consumption by 7 percent, increased HC emissions by 5 percent, increased CO emissions by 4%, and increased Nox emissions by 4 percent.

5.2.4.2 Sensitivity Analysis of Vehicle Occupancy Distribution and Anticipated Future Growth

As mentioned earlier, the vehicle occupancy distribution and anticipated future growth have a significant impact on the success of an added HOV lane operation. Thus a sensitivity analysis was undertaken in which the percent of vehicles carrying 2+ persons will vary from 10% to 30% (with 20% 2+ vehicles representing base conditions). The freeway demand level was also varied from 0.95 to 1.10 (in steps of 0.05) with an initial value of 1.00 representing the year 2004 freeway demand level.

The detailed results of these sensitivity analysis investigations are summarized in Figures 5.12, 5.13, 5.14, and 5.15 with each figure representing a different freeway demand level (0.95, 1.00, 1.05, and 1.10). The rows in each figure represent measures of performances while the vertical columns represent the percent vehicles carry 2+ vehicles ranging from 10% to 30%. The detailed results for each of the four freeway demand levels are discussed in the following four sections. But first, a discussion of an over-riding factor should be considered.

The current model assumes that the HOV lane design parameters are selected that will result in the operations in the HOV lane to be superior to the operations in the adjacent mixed-flow lanes. HOV vehicles are assumed to use the HOV lane and assigned to use it. As will be shown, in some situations the simulated operations in the HOV lane for individual HOV users are found not to be superior to the simulated operations in the mixed-flow lane and the assignment of HOV vehicles is not reasonable. Hence the predicted performance is not realistic. These results are only available once the set of investigations is completed. Hence all results will be presented but the over-riding factor of comparative level of operations between the HOV and mixed-flow lanes must be considered in the final analysis.

5.2.4.3 Impact of 2+ HOV Lane with 0.95 Freeway Demand Level

Figure 5.12 presents the impacts of a 2+ HOV lane with a freeway demand level of 0.95 and with a varying percent of vehicles carrying 2+ persons from 10% to 30%.

Three types of HOV lane operations were encountered as the percentage increased. With percent of vehicles carrying 2+ persons varying from 10% to 20%, there was no congestion in the HOV lane or in the non-HOV lanes and little motivation for HOV vehicles to use the HOV lane. These results are similar to adding a mixed-flow lane rather than a HOV lane. With the percentage of vehicles carrying 2+ persons set at 22%, there was congestion in the HOV lane. With the percentage of vehicles carrying 2+ persons greater than 22%, there was severe congestion in the HOV lane and there was a queue out of the HOV lane due to the congestion in the HOV lane. Hence, there is little incentive to consider adding a HOV lane at this freeway demand level.

With percent of vehicles carrying 2+ persons varying from 10% to 20%, the total time and delay decreased from -803 to -1067 passenger-hours. There was essentially no change in the total passenger-miles served at any 2+ vehicle percentage levels since all of the traffic that wished to travel during the peak period were able to be served during the peak period. There was a 4 mph increase in overall average speeds for HOV vehicles and a 3 to 4 mph increase in overall average speeds of non-HOV vehicles. Fuel consumed increased from 1778 to 2225 gallons as 2+percentages increased. Total emissions increased by 125 to 171 kilograms as 2+ percentages increased. The net increase in the fuel consumption and total emissions was due to the savings due to reduced congestion being less than the increase due to higher freeway speeds.

5.2.4.4 Impact of 2+ HOV Lane with 1.00 Freeway Growth Level

Figure 5.13 presents the impacts of a 2+ HOV lane with a freeway demand level of 1.00 and with a varying percent of vehicles carrying 2+ persons from 10% to 30%.

Three types of HOV lane operations were encountered as the percentage increased. With percent of vehicles carrying 2+ persons varying from 10% to 20%, there was no congestion in the HOV lane or in the non-HOV lanes and little motivation for HOV vehicles to use the HOV lane. These results are similar to adding a mixed-flow lane rather than a HOV lane. With the percentage of vehicles carrying 2+ persons set at 22%, there was congestion in the HOV lane. With the percentage of vehicles carrying 2+ persons greater than 22%, there was severe congestion in the HOV lane and there was a queue out of the HOV lane due to the congestion in the HOV lane. Hence, there is little incentive to consider adding a HOV lane at this freeway demand level.

5.2.4.5 Impact of 2+ HOV Lane with 1.05 Freeway Growth Level

Figure 5.14 presents the impacts of a 2+ HOV lane with a freeway demand level of 1.05 and with a varying percent of vehicles carrying 2+ persons from 10% to 30%.

Three types of HOV lane operations were encountered as the percentage increased. With percent of vehicles carrying 2+ persons varying from 10% to 16%, there was no congestion in the HOV lane or in the non-HOV lanes and little motivation for HOV vehicles to use the HOV lane. These results are similar to adding a mixed-flow lane rather than a HOV lane. With the percentage of vehicles carrying 2+ persons set at 20%, there was considerable congestion in the HOV lane. With the percentage of vehicles carrying 2+ persons greater than 20%, there was severe congestion in the HOV lane and there was a queue extending out of the HOV lane due to the congestion in the HOV lane. Hence, there is little incentive to consider adding a HOV lane at this freeway demand level.

With percent of vehicles carrying 2+ persons varying from 10% to 16%, the total time and delay decreased from -8916 to -10136 passenger-hours. There was an approximate increase in total passenger-miles served of 5% since all of the traffic that wished to travel during the peak period were able to be served during the peak period with the added HOV lane. There was a 28 mph increase in overall average speeds for HOV vehicles and a 24 to 26 mph increase in overall average speeds of non-HOV vehicles. Fuel consumed increased from 1305 to 2618 gallons as 2+percentages increased. Total emissions were reduced by 55 kilograms with 10% 2+ HOV vehicles and increased by 33 kilograms with 16% 2+ HOV vehicles.

5.2.4.6 Impact of 2+ HOV Lane with 1.10 Freeway Growth Level

Figure 5.15 presents the impacts of a 2+ HOV lane with a freeway demand level of 1.10 and with a varying percent of vehicles carrying 2+ persons from 10% to 30%.

Three types of HOV lane operations were encountered as the percentage increased. With percent of vehicles carrying 2+ persons varying from 10% to 16%, there was no congestion in the HOV lane and the congestion in the non-HOV lanes varied from moderate congestion to no congestion. With the percentage of vehicles carrying 2+ persons set between 16 and 20%, there was considerable congestion in the HOV lane. With the percentage of vehicles carrying 2+ persons greater than 20%, there was severe congestion in the HOV lane and there was a queue extending out of the HOV lane due to the congestion in the HOV lane. At the lower percentages of HOV vehicles, there was motivation for HOV vehicles to use the HOV lane and the simulated results were reasonable. However at higher percentages of HOV vehicles, there is little incentive to consider adding a HOV lane at this freeway demand level.

With percent of vehicles carrying 2+ persons varying from 10% to 16%, the total time and delay decreased from -8835 to -11908 passenger-hours. There was an approximate increase in total passenger-miles served of 9% since all of the traffic that wished to travel during the peak period were able to be served during the peak period with the added HOV lane. There was a 32 mph increase in overall average speeds for HOV vehicles and a 18 to 28 mph increase in overall average speeds of non-HOV vehicles. Fuel consumed increased from 2076 to 3232 gallons as 2+percentages increased. Total emissions were increased from 16 to 54 kilograms as 2+ percentages increased.

5.2.4.7 Overall Summary of Results on Each Measure of Performance

Sensitivity of results presented on a percentage basis for eight selected measures of performance is shown in Figures 5.16A, 5.16B, 5.16C, and 5.16D. Recall that the base conditions assume that 20% of the vehicles carry 2+ persons and the growth factor is 1.00. Only the results when the 2+ HOV is less than 20% are discussed in the following paragraphs since with higher 2+ HOV is greater than 20% the HOV lane is congested and in extremely cases, queues from the HOV lane congestion extend out of the HOV lane section. Also recall that except at the higher demand levels combined with the lower 2+ vehicle percentages are there incentives for HOV vehicles to use the HOV lane and the simulation results are more indicative of adding a mixed-flow lane rather than a HOV lane.

Comments on each of the sixteen selected measures of performance are presented in the following sixteen paragraphs.

The percent change in total time and delay in passenger-hours is always reduced with the introduction of a HOV lane and varied from -6 to -40 %. The smallest reductions (less than 7%) occur when the demand growth level was the lowest while the largest reductions (over 30%) occur when the demand growth level was the highest. The base condition resulted in a 24% reduction (Figure 5.16A).

The percent change in freeway travel time in passenger-miles was never reduced with the introduction of a HOV lane and the increase varied from 0% to 9 %. Any increase in passenger-miles of travel occurred because the peak period demand was not served within the study duration period in the analysis of the before added HOV lane situation. These unserved vehicles were transferred to time periods beyond the study duration period and not included in the analysis. Therefore more people and vehicles were served within the study duration period with the HOV lane added particularly with the higher demand growth. The base condition results in a 1% increase (Figure 5.16A).

The percent change in overall average HOV vehicle speeds in mph always increased with the introduction of a HOV lane and the increase varied from 7 to 94 %. The higher demand growth levels investigated resulted in greater increases in HOV speeds because the speeds of HOV vehicles before the introduction of the HOV lane were very low. The base condition resulted in a 31% increase in HOV vehicle speeds (Figure 5.16A).

The percent change in overall average non-HOV vehicle speeds in mph always increased with the introduction of a HOV lane and the increase varied from 6 to 83%. The reason why the non-HOV speeds always increased was that the demand in the non-HOV lanes was reduced due to HOV vehicles using the HOV lane. The larger increases occurred when the demand growth was the highest. The base condition resulted in a 34% increase in non-HOV vehicle speeds (Figure 5.16A).

The percent change in total fuel consumed varied from +3% to +8% with the greatest increases occurring at higher demand levels. This was due to higher speeds in both the HOV and non-HOV lanes. Also keep in mind that more people and vehicles were served with the introduction of the HOV lane. The base condition resulted in a 6% increase in fuel consumption (Figure 5.16B).

The percentage change in total emissions varied from –1% to +5% with the greatest increases occurring at lower demand levels. The base condition resulted in a 4% increase in vehicle emissions (Figure 5.16B).

Another set of results that is often helpful is the level of flow in the HOV lane. Low flows in the HOV lane indicate that the added HOV lane is not being effectively used and also non-HOV users particularly may be concerned about this under-utilization. Obviously high flows approaching the capacity of the HOV lane are of concern because of the poor level of service being provided to HOV users and also because of not having available capacity for future HOV growth. Too high a flow in the HOV lane was a problem in these sensitivity investigations. Investigations at lower 2+ HOV percentages combined with lower levels of traffic demands resulted in low flows in the HOV lane. Investigations at higher 2+ HOV percentages combined with higher levels of traffic demands resulted in congestion in the HOV lane. The base condition resulted in a flow level that generally did not exceed 800 to 1400 vehicles per hour (Figure 5.16B).

Another set of results that is often informative is the level of freeway congestion before introducing the HOV lane and then the level of freeway congestion in the HOV and non-HOV lanes after the introduction of the HOV lane. For each cell in the eighth table of Figure 5.16 there is a code of three letters indicating the level of freeway congestion before the HOV is introduced and then the level of congestion in the HOV lane and the non-HOV lane. The following letters are used to indicate the level of congestion: no congestion (N), light congestion (L), moderate congestion (M), and heavy congestion (H). The designation of light, moderate, and heavy congestion is determined qualitatively for comparison purposes. It is most important to note that congestion is predicted in the HOV lane when the percentage of 2+ HOV vehicles approaches 20% and the demand level is greater than 0.95. Also observe that there is no congestion in the non-HOV lanes with lower demand levels and therefore little motivation for HOV lane current usage or growth. The base condition resulted in moderate congestion before the introduction of the HOV and some congestion in the HOV lane and no congestion in the non-HOV lanes (Figure 5.16B).

The four tables contained in Figure 5.16C provide total quantities expended in fuel consumption, vehicle emissions, passenger time, and passenger travel. These total quantities can be misleading in assessing the implementation of HOV lanes. For example, the total passenger-miles traveled within the study section and study duration period varied between investigations. Hence total fuel consumption, vehicle emissions, and passenger-hours would be expected to vary due to different levels of total passenger-miles of travel as well as due to the appropriateness of the HOV lane design. The total quantities shown in Figure 5.16C were used to create the first three tables contained in Figure 5.16D.

Average fuel consumption rates (passenger-miles per gallon) are displayed in the first table of Figure 5.16D. The average fuel consumption under the base conditions of 20% HOV vehicles and growth factor of 1.00 was 24.4 pass-miles/gal. Any increase in % HOV vehicle level resulted in the HOV lane becoming congested and queues extending back into the non-HOV lanes. Lower fuel consumption rates were observed at lower % HOV vehicle levels.

Average vehicle emission rates (passenger-miles per kilogram) are displayed in the second table of Figure 5.16D. The average vehicle emission rate under the base conditions was 281 pass-miles/kg. Any increase in % HOV vehicle level resulted in the HOV lane becoming congested and queues extending back into the non-HOV lanes. Lower vehicle emission rates were observed at lower % HOV vehicle levels.

Average vehicle speeds (miles per hour) are displayed in the third table of Figure 5.16D. Another way of looking at this rate is in terms of passenger-miles traveled per hour of time. Average vehicle speed under the base conditions was 63.7 mph. Any increase in % HOV vehicle level resulted in the HOV lane becoming congested and queues extending back into the non-HOV lanes. Average speeds at lower % HOV vehicle levels varied depending primarily upon the % HOV vehicle level.

The final table in Figure 5.16D displays the differential average speeds between the HOV lane and the non-HOV lanes for various traffic demand levels and percentage of 2+ HOV vehicles. Little difference is expected between the HOV lane average speed and the average speed in the non-HOV lanes under the base conditions. Any increase in % HOV vehicle level resulted in the HOV lane becoming congested and queues extending back into the non-HOV lanes. In only a few cases were the differential speeds predicted to be greater than 5 mph.

DIFFERENTIAL EFFECTS TABLE AFTER (DAY+1)

		BEFORE IMPLEMENTATION			AFTER IMPLEMENTATION			DIFFERENCES			
		FREEWAY	ALT.RTE	TOTAL	FREEWAY	ALT.RTE	TOTAL	FREEWAY	ART.RTE	TOTAL	PER.CHANGE
TRAVEL TIME	VEH-HR	16642.	0.	16642.	12641.	0.	12641.	-4000.	0.	-4000.	-24.04
	PASS-HR	20968.	0.	20968.	15995.	0.	15995.	-4974.	0.	-4974.	-23.72
TRAVEL DISTANCE	VEH-MI	798987.	0.	798987.	808496.	0.	808496.	9508.	0.	9508.	1.19
	PASS-MI	1006723.	0.	1006723.	1018904.	0.	1018904.	12181.	0.	12181.	1.21
AVG.SPD.	MPH.	48.15	0.00	48.15	64.36	0.00	64.36	16.21	0.00	16.21	33.66
GASOLINE	GALLONS	39219.	0.	39219.	41786.	0.	41786.	2567.	0.	2567.	6.55
HYD-CARB	KILOGRAMS	246.	0.	246.	258.	0.	258.	12.	0.	12.	4.92
CARB-MON	KILOGRAMS	2968.	0.	2968.	3074.	0.	3074.	107.	0.	107.	3.60
NIT.-OX.	KILOGRAMS	284.	0.	284.	295.	0.	295.	11.	0.	11.	3.83
ALL-EMIS	KILOGRAMS	3498.	0.	3498.	3627.	0.	3627.	130.	0.	130.	3.71

Figure 5.11 Differential Effects of Performance Measures by Adding 2+ HOV Lane

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE (GF=0.95)									FILE=I580EP-FN2	
MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 0.95 2+ HOV = 10%	GF = 0.95 2+ HOV = 13%	GF = 0.95 2+ HOV = 16%	GF = 0.95 2+ HOV = 20%	GF = 0.95 2+ HOV = 22%	GF = 0.95 2+ HOV = 23%	GF = 0.95 2+ HOV = 25%	GF = 0.95 2+ HOV = 28%	GF = 0.95 2+ HOV = 30%
FREEWAY	W/O HOV LANE	14267	14800	15333	15993	16399				
TRAVEL TIME	WITH HOV LANE	13463	13887	14326	14925	16795	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**
PASS-HRS	DIFFERENCE	-804	-913	-1007	-1068	396				
	% DIFFERENCE	-5.6	-6.2	-6.6	-6.7	2.4				
RAMP	W/O HOV LANE	28	29	30	31	32				
DELAY	WITH HOV LANE	29	29	30	32	25	**OUT**	**OUT**	**OUT**	**OUT**
PASS-HRS	DIFFERENCE	1	0	0	1	-7				
	% DIFFERENCE	3.6	0.0	0.0	3.2	-21.9				
TOTAL	W/O HOV LANE	14295	14829	15363	16024	16431				
TIME & DELAY	WITH HOV LANE	13492	13916	14356	14957	16820	**OF**	**OF**	**OF**	**OF**
PASS-HRS	DIFFERENCE	**-803**	**-913**	**-1007**	**-1067**	**389**				
	% DIFFERENCE	-5.6	-6.2	-6.6	-6.7	2.4				
FREEWAY	W/O HOV LANE	864226	896519	928812	968795	993399				
TRAVEL	WITH HOV LANE	863997	896282	928566	968538	989110	**HOV**	**HOV**	**HOV**	**HOV**
PASS-MILES	DIFFERENCE	**-229**	**-237**	**-246**	**-257**	**-4289**				
	% DIFFERENCE	0.0	0.0	0.0	0.0	-0.4				
FREEWAY	W/O HOV LANE	60.6	60.6	60.6	60.6	60.6				
AVG SPEED	HOV LANE	65.0	65.0	65.0	64.8	51.0	**LANE**	**LANE**	**LANE**	**LANE**
MPH	MIXED-FLOW	64.0	64.4	64.7	64.9	65.0				
	HOV DIFF	**4.4**	**4.4**	**4.4**	**4.2**	**-9.6**				
	NON-HOV DIFF	**3.4**	**3.8**	**4.1**	**4.3**	**4.4**				
	% DIFF HOV	7.3	7.3	7.3	6.9	-15.8				
	%DIFF NON-HOV	5.6	6.3	6.8	7.1	7.3				
TOTAL FUEL	W/O HOV LANE	37803	37803	37803	37803	37803				
CONSUMED	WITH HOV LANE	39581	39824	40013	40028	39667	**DUE**	**DUE**	**DUE**	**DUE**
GALLONS	DIFFERENCE	**1778**	**2021**	**2210**	**2225**	**1864**				
	% DIFFERENCE	4.7	5.3	5.8	5.9	4.9				
EMFAC2002	W/O HOV LANE	226	226	226	226	226				
HC EMISSIONS	WITH HOV LANE	242	245	247	248	247	**TO**	**TO**	**TO**	**TO**
KILOGRAMS	DIFFERENCE	16	19	21	22	21				
	% DIFFERENCE	7.1	8.4	9.3	9.7	9.3				
EMFAC2002	W/O HOV LANE	2797	2797	2797	2797	2797				
CO EMISSIONS	WITH HOV LANE	2897	2915	2929	2937	2935	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**
KILOGRAMS	DIFFERENCE	100	118	132	140	138				
	% DIFFERENCE	3.6	4.2	4.7	5.0	4.9				
EMFAC2002	W/O HOV LANE	273	273	273	273	273				
NO EMISSIONS	WITH HOV LANE	281	282	283	282	280	**IN**	**IN**	**IN**	**IN**
KILOGRAMS	DIFFERENCE	8	9	10	9	7				
	% DIFFERENCE	2.9	3.3	3.7	3.3	2.6				
EMFAC2002	W/O HOV LANE	3296	3296	3296	3296	3296				
TOTAL EMISSION	WITH HOV LANE	3421	3442	3459	3467	3462	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**
KILOGRAMS	DIFFERENCE	**125**	**146**	**163**	**171**	**166**				
	% DIFFERENCE	3.8	4.4	4.9	5.2	5.0				

Figure 5.12 Effect of Demand Growth and 2+ Vehicle Percentages on Performance of Full Length No Barrier HOV Lane (GF=0.95)

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE (GF=1.00)										FILE=I580EP-FN2
MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 1.00 2+ HOV = 10%	GF = 1.00 2+ HOV = 13%	GF = 1.00 2+ HOV = 16%	GF = 1.00 2+ HOV = 20%	GF = 1.00 2+ HOV = 22%	GF = 1.00 2+ HOV = 23%	GF = 1.00 2+ HOV = 25%	GF = 1.00 2+ HOV = 28%	GF = 1.00 2+ HOV = 30%
FREEWAY	W/O HOV LANE	18650	19346	20043	20906					
TRAVEL TIME	WITH HOV LANE	14381	14745	15161	15896	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**
PASS-HRS	DIFFERENCE	-4269	-4601	-4882	-5010					
	% DIFFERENCE	-22.9	-23.8	-24.4	-24.0					
RAMP	W/O HOV LANE	56	58	60	62					
DELAY	WITH HOV LANE	88	90	94	99	**OUT**	**OUT**	**OUT**	**OUT**	**OUT**
PASS-HRS	DIFFERENCE	32	32	34	37					
	% DIFFERENCE	57.1	55.2	56.7	59.7					
TOTAL	W/O HOV LANE	18705	19404	20103	20968					
TIME & DELAY	WITH HOV LANE	14469	14835	15255	15995	**OF**	**OF**	**OF**	**OF**	**OF**
PASS-HRS	DIFFERENCE	**-4236**	**-4569**	**-4848**	**-4973**					
	% DIFFERENCE	-22.6	-23.5	-24.1	-23.7					
FREEWAY	W/O HOV LANE	898061	931619	965176	1006723					
TRAVEL	WITH HOV LANE	908533	942482	976431	1018904	**HOV**	**HOV**	**HOV**	**HOV**	**HOV**
PASS-MILES	DIFFERENCE	**10472**	**10863**	**11255**	**12181**					
	% DIFFERENCE	1.2	1.2	1.2	1.2					
FREEWAY	W/O HOV LANE	48.2	48.2	48.2	48.2					
AVG SPEED	HOV LANE	65.0	65.0	65.0	63.1	**LANE**	**LANE**	**LANE**	**LANE**	**LANE**
MPH	MIXED-FLOW	62.8	63.6	64.2	64.7					
	HOV DIFF	**16.8**	**16.8**	**16.8**	**14.9**					
	NON-HOV DIFF	**14.6**	**15.4**	**16.0**	**16.5**					
	% DIFF HOV	34.9	34.9	34.9	30.9					
	%DIFF NON-HOV	30.3	32.0	33.2	34.2					
TOTAL FUEL	W/O HOV LANE	39219	39219	39219	39219					
CONSUMED	WITH HOV LANE	40775	41314	41673	41786	**DUE**	**DUE**	**DUE**	**DUE**	**DUE**
GALLONS	DIFFERENCE	**1556**	**2095**	**2454**	**2567**					
	% DIFFERENCE	4.0	5.3	6.3	6.5					
EMFAC2002	W/O HOV LANE	246	246	246	246					
HC EMISSIONS	WITH HOV LANE	248	253	256	258	**TO**	**TO**	**TO**	**TO**	**TO**
KILOGRAMS	DIFFERENCE	2	7	10	12					
	% DIFFERENCE	0.8	2.8	4.1	4.9					
EMFAC2002	W/O HOV LANE	2968	2968	2968	2968					
CO EMISSIONS	WITH HOV LANE	3003	3036	3060	3074	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**
KILOGRAMS	DIFFERENCE	35	68	92	106					
	% DIFFERENCE	1.2	2.3	3.1	3.6					
EMFAC2002	W/O HOV LANE	284	284	284	284					
NO EMISSIONS	WITH HOV LANE	291	293	295	295	**IN**	**IN**	**IN**	**IN**	**IN**
KILOGRAMS	DIFFERENCE	7	9	11	11					
	% DIFFERENCE	2.5	3.2	3.9	3.9					
EMFAC2002	W/O HOV LANE	3498	3498	3498	3498					
TOTAL EMISSION	WITH HOV LANE	3542	3582	3611	3627	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**
KILOGRAMS	DIFFERENCE	**44**	**84**	**113**	**129**					
	% DIFFERENCE	1.3	2.4	3.2	3.7					

Figure 5.13 Effect of Demand Growth and 2+ Vehicle Percentages on Performance of Full Length No Barrier HOV Lane (GF=1.00)

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE (GF=1.05) FILE=I580EP-FN2

MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 1.05 2+ HOV = 10%	GF = 1.05 2+ HOV = 13%	GF = 1.05 2+ HOV = 16%	GF = 1.05 2+ HOV = 20%	GF = 1.05 2+ HOV = 22%	GF = 1.05 2+ HOV = 23%	GF = 1.05 2+ HOV = 25%	GF = 1.05 2+ HOV = 28%	GF = 1.05 2+ HOV = 30%
FREEWAY	W/O HOV LANE	24407	25319	26231	27360					
TRAVEL TIME	WITH HOV LANE	15464	15729	16067	18239	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**
PASS-HRS	DIFFERENCE	-8943	-9590	-10164	-9121					
	% DIFFERENCE	-36.6	-37.9	-38.7	-33.3					
RAMP	W/O HOV LANE	267	277	287	299					
DELAY	WITH HOV LANE	293	303	314	266	**OUT**	**OUT**	**OUT**	**OUT**	**OUT**
PASS-HRS	DIFFERENCE	26	26	27	-33					
	% DIFFERENCE	9.7	9.4	9.4	-11.0					
TOTAL	W/O HOV LANE	24673	25595	26517	27659					
TIME & DELAY	WITH HOV LANE	15757	16032	16381	18505	**OF**	**OF**	**OF**	**OF**	**OF**
PASS-HRS	DIFFERENCE	**-8916**	**-9563**	**-10136**	**-9154**					
	% DIFFERENCE	-36.1	-37.4	-38.2	-33.1					
FREEWAY	W/O HOV LANE	908148	942083	976017	1018031					
TRAVEL	WITH HOV LANE	953321	988697	1024295	1063665	**HOV**	**HOV**	**HOV**	**HOV**	**HOV**
PASS-MILES	DIFFERENCE	**45173**	**46614**	**48278**	**45634**					
	% DIFFERENCE	5.0	4.9	4.9	4.5					
FREEWAY	W/O HOV LANE	37.2	37.2	37.2	37.2					
AVG SPEED	HOV LANE	65.0	65.0	65.0	49.8	**LANE**	**LANE**	**LANE**	**LANE**	**LANE**
MPH	MIXED-FLOW	60.9	62.2	63.3	64.1					
	HOV DIFF	**27.8**	**27.8**	**27.8**	**12.6**					
	NON-HOV DIFF	**23.7**	**25.0**	**26.1**	**26.9**					
	% DIFF HOV	74.7	74.7	74.7	33.9					
	%DIFF NON-HOV	63.7	67.2	70.2	72.3					
TOTAL FUEL	W/O HOV LANE	40530	40530	40530	40530					
CONSUMED	WITH HOV LANE	41835	42438	43148	43277	**DUE**	**DUE**	**DUE**	**DUE**	**DUE**
GALLONS	DIFFERENCE	**1305**	**1908**	**2618**	**2747**					
	% DIFFERENCE	3.2	4.7	6.5	6.8					
EMFAC2002	W/O HOV LANE	273	273	273	273					
HC EMISSIONS	WITH HOV LANE	253	258	264	269	**TO**	**TO**	**TO**	**TO**	**TO**
KILOGRAMS	DIFFERENCE	-20	-15	-9	-4					
	% DIFFERENCE	-7.3	-5.5	-3.3	-1.5					
EMFAC2002	W/O HOV LANE	3154	3154	3154	3154					
CO EMISSIONS	WITH HOV LANE	3112	3143	3183	3213	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**
KILOGRAMS	DIFFERENCE	-42	-11	29	59					
	% DIFFERENCE	-1.3	-0.3	0.9	1.9					
EMFAC2002	W/O HOV LANE	293	293	293	293					
NO EMISSIONS	WITH HOV LANE	300	303	306	306	**IN**	**IN**	**IN**	**IN**	**IN**
KILOGRAMS	DIFFERENCE	7	10	13	13					
	% DIFFERENCE	2.4	3.4	4.4	4.4					
EMFAC2002	W/O HOV LANE	3720	3720	3720	3720					
TOTAL EMISSION	WITH HOV LANE	3665	3704	3753	3788	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**
KILOGRAMS	DIFFERENCE	**-55**	**-16**	**33**	**68**					
	% DIFFERENCE	-1.5	-0.4	0.9	1.8					

Figure 5.14 Effect of Demand Growth and 2+ Vehicle Percentages on Performance of Full Length No Barrier HOV Lane (GF=1.05)

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE (GF=1.10)

FILE=I580EP-FN2

MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 1.10 2+ HOV = 10%	GF = 1.10 2+ HOV = 13%	GF = 1.10 2+ HOV = 16%	GF = 1.10 2+ HOV = 20%	GF = 1.10 2+ HOV = 22%	GF = 1.10 2+ HOV = 23%	GF = 1.10 2+ HOV = 25%	GF = 1.10 2+ HOV = 28%	GF = 1.10 2+ HOV = 30%
FREEWAY	W/O HOV LANE	27192	28208	29224						
TRAVEL TIME	WITH HOV LANE	18384	16925	17137	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**
PASS-HRS	DIFFERENCE	-8808	-11283	-12087						
	% DIFFERENCE	-32.4	-40.0	-41.4						
RAMP	W/O HOV LANE	844	875	907						
DELAY	WITH HOV LANE	816	1057	1085	**OUT**	**OUT**	**OUT**	**OUT**	**OUT**	**OUT**
PASS-HRS	DIFFERENCE	-28	182	178						
	% DIFFERENCE	-3.3	20.8	19.6						
TOTAL	W/O HOV LANE	28035	29083	30130						
TIME & DELAY	WITH HOV LANE	19200	17982	18222	**OF**	**OF**	**OF**	**OF**	**OF**	**OF**
PASS-HRS	DIFFERENCE	**-8835**	**-11101**	**-11908**						
	% DIFFERENCE	-31.5	-38.2	-39.5						
FREEWAY	W/O HOV LANE	911595	945658	979722						
TRAVEL	WITH HOV LANE	993581	1034708	1071805	**HOV**	**HOV**	**HOV**	**HOV**	**HOV**	**HOV**
PASS-MILES	DIFFERENCE	**81986**	**89050**	**92083**						
	% DIFFERENCE	9.0	9.4	9.4						
FREEWAY	W/O HOV LANE	33.5	33.5	33.5						
AVG SPEED	HOV LANE	65.0	65.0	65.0	**LANE**	**LANE**	**LANE**	**LANE**	**LANE**	**LANE**
MPH	MIXED-FLOW	52.0	60.0	61.6						
	HOV DIFF	**31.5**	**31.5**	**31.5**						
	NON-HOV DIFF	**18.5**	**26.5**	**28.1**						
	% DIFF HOV	94.0	94.0	94.0						
	%DIFF NON-HOV	55.2	79.1	83.9						
TOTAL FUEL	W/O HOV LANE	41150	41150	41150						
CONSUMED	WITH HOV LANE	43226	43712	44382	**DUE**	**DUE**	**DUE**	**DUE**	**DUE**	**DUE**
GALLONS	DIFFERENCE	**2076**	**2562**	**3232**						
	% DIFFERENCE	5.0	6.2	7.9						
EMFAC2002	W/O HOV LANE	287	287	287						
HC EMISSIONS	WITH HOV LANE	269	267	273	**TO**	**TO**	**TO**	**TO**	**TO**	**TO**
KILOGRAMS	DIFFERENCE	-18	-20	-14						
	% DIFFERENCE	-6.3	-7.0	-4.9						
EMFAC2002	W/O HOV LANE	3260	3260	3260						
CO EMISSIONS	WITH HOV LANE	3279	3275	3308	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**
KILOGRAMS	DIFFERENCE	19	15	48						
	% DIFFERENCE	0.6	0.5	1.5						
EMFAC2002	W/O HOV LANE	297	297	297						
NO EMISSIONS	WITH HOV LANE	312	314	317	**IN**	**IN**	**IN**	**IN**	**IN**	**IN**
KILOGRAMS	DIFFERENCE	15	17	20						
	% DIFFERENCE	5.1	5.7	6.7						
EMFAC2002	W/O HOV LANE	3844	3844	3844						
TOTAL EMISSION	WITH HOV LANE	3860	3856	3898	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**
KILOGRAMS	DIFFERENCE	**16**	**12**	**54**						
	% DIFFERENCE	0.4	0.3	1.4						

Figure 5.15 Effect of Demand Growth and 2+ Vehicle Percentages on Performance of Full Length No Barrier HOV Lane (GF=1.10)

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE										FILE = I580EP-FN2
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
TOTAL	0.95	**-5.6**	**-6.2**	**-6.6**	**-6.7**	**2.4**				
TIME & DELAY	1.00	**-22.6**	**-23.5**	**-24.1**	**-23.7**					
PASS-HRS	1.05	**-36.1**	**-37.4**	**-38.2**	**-33.1**					
(% Change)	1.10	**-31.5**	**-38.2**	**-39.5**						

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE										FILE = I580EP-FN2
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
FREEWAY	0.95	**0.0**	**0.0**	**0.0**	**0.0**	**-0.4**				
TRAVEL	1.00	**1.2**	**1.2**	**1.2**	**1.2**					
PASS-MILES	1.05	**5.0**	**4.9**	**4.9**	**4.5**					
(% Change)	1.10	**9.0**	**9.4**	**9.4**						

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE										FILE = I580EP-FN2
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
HOV VEHICLES	0.95	**7.3**	**7.3**	**7.3**	**6.9**	**-15.8**				
AVG SPEED	1.00	**34.9**	**34.9**	**34.9**	**30.9**					
MPH	1.05	**74.7**	**74.7**	**74.7**	**33.9**					
(% Change)	1.10	**94.0**	**94.0**	**94.0**						

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE										FILE = I580EP-FN2
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
NON-HOV	0.95	**5.6**	**6.3**	**6.8**	**7.1**	**7.3**				
VEHICLE	1.00	**30.3**	**32.0**	**33.2**	**34.2**					
AVG SPEED	1.05	**63.7**	**67.2**	**70.2**	**72.2**					
MPH (% Change)	1.10	**55.2**	**79.1**	**83.9**						

Figure 5.16A Summary Effect of Demand Growth Level and 2+ Vehicle Percentages on Performance of Full Length No Barrier HOV Lane

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE									FILE =	I580EP-FN2
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
TOTAL FUEL	0.95	**4.7**	**5.3**	**5.8**	**5.9**	**4.9**				
CONSUMED	1.00	**4.0**	**5.3**	**6.3**	**6.5**					
GALLONS	1.05	**3.2**	**4.7**	**6.5**	**6.8**					
(% Change)	1.10	**5.0**	**6.2**	**7.9**						

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE									FILE =	I580EP-FN2
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
EMFAC2002	0.95	**3.8**	**4.4**	**4.9**	**5.2**	**5.0**				
TOTAL EMISSION	1.00	**1.3**	**2.4**	**3.2**	**3.7**					
KILOGRAMS	1.05	**-1.5**	**-0.4**	**0.9**	**1.8**					
(% Change)	1.10	**0.4**	**0.3**	**1.4**						

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE									FILE =	I580EP-FN2
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
FLOW LEVEL	0.95	**400-700**	**500-1000**	**700-1100**	**700-1400**	**700-1500**				
IN HOV LANE	1.00	**400-700**	**500-1000**	**700-1100**	**800-1500**					
(VEHS/HOUR)	1.05	**500-800**	**700-1000**	**700-1300**	**1100-1500**					
	1.10	**500-800**	**800-1100**	**800-1400**						

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE									FILE =	I580EP-FN2
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
LEVEL OF	0.95	**L/N/N**	**L/N/N**	**L/N/N**	**L/N/N**	**L/H/N**				
FREEWAY	1.00	**M/N/N**	**M/N/N**	**M/N/N**	**M/L/N**					
CONGESTION	1.05	**H/N/L**	**H/N/N**	**H/N/N**	**H/H/N**					
	1.10	**H/N/M**	**H/N/L**	**H/N/N**						
X/Y/Z = LEVEL OF FREEWAY CONGESTION : BEFORE/HOV LANE/NON-HOV LANES						N= NONE	L=LIGHT		M=MODERATE	H=HEAVY

Figure 5.16B Summary Effect of Demand Growth Level and 2+ Vehicle Percentages on Performance of Full Length No Barrier HOV Lane

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE										FILE = I580EP-FN3
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
TOTAL FUEL	0.95	39581	39824	40013	40028	39667				
CONSUMED	1.00	40775	41314	41673	41786					
(GALLONS)	1.05	41835	42438	43148	43277					
	1.10	43226	43712	44382						

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE										FILE = I580EP-FN3
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
EMFAC2002	0.95	3421	3442	3459	3467	3462				
TOTAL EMISSION	1.00	3542	3582	3611	3627					
(KILOGRAMS)	1.05	3665	3704	3753	3788					
	1.10	3860	3856	3898						

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE										FILE = I580EP-FN3
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
TOTAL TIME	0.95	13492	13916	14356	14957	16820				
AND DELAY	1.00	14469	14835	15255	15995					
(PASS-HRS)	1.05	15757	16032	16381	18505					
	1.10	* 19200	17982	18222						

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE										FILE = I580EP-FN3
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
TOTAL TRAVEL	0.95	863997	896282	928566	968538	989110				
DISTANCE	1.00	908533	942482	976431	1018904					
(PASS-MILES)	1.05	953321	988697	1024295	1063665					
	1.10	993581	1034708	1071805						

* Congestion extends beyond the last time slice and/or upstream of the first subsection causing the time and delay to be underestimated"

Figure 5.16C Summary Effect of Demand Growth Level and 2+ Vehicle Percentages on Performance of Full Length No Barrier HOV Lane

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE									FILE =	I580EP-FN3
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
AVERAGE	0.95	21.8	22.5	23.2	24.2	24.9				
FUEL	1.00	22.3	22.8	23.4	24.4					
CONSUMPTION	1.05	22.8	23.3	23.7	24.6					
(Pass-Miles/Gal)	1.10	23.0	23.7	24.1						

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE									FILE =	I580EP-FN3
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
AVERAGE	0.95	253	260	268	279	286				
VEHICLE	1.00	257	263	270	281					
EMISSIONS	1.05	260	267	273	281					
(Pass-Miles/Kg)	1.10	257	268	275						

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE									FILE =	I580EP-FN3
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
AVERAGE	0.95	64.0	64.4	64.7	64.8	58.8				
VEHICLE	1.00	62.8	63.5	64.0	63.7					
SPEEDS	1.05	60.5	61.7	62.5	57.5					
(mph)	1.10	51.7	57.5	58.8						

EFFECT OF DEMAND GROWTH LEVEL AND 3+ VEHICLE PERCENTAGES ON PERFORMANCE OF FULL LENGTH NO BARRIER HOV LANE									FILE =	I580EP-FN3
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 10%	2+ HOV = 13%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 22%	2+ HOV = 23%	2+ HOV = 25%	2+ HOV = 28%	2+ HOV = 30%
HOV SPEED	0.95	1.0	0.6	0.3	-0.1	-14.0				
MINUS	1.00	2.2	1.4	0.8	-1.6					
NON HOV SPEED	1.05	4.1	2.8	1.7	-14.3					
(mph)	1.10	13.0	5.0	3.4						

Figure 5.16D Summary Effect of Demand Growth Level and 2+ Vehicle Percentages on Performance of Full Length No Barrier HOV Lane

5.3 DEMONSTRATION APPLICATION ON THE SOUTHERN CALIFORNIA SITE

The process followed and the results obtained in the demonstration application on the southern California site are covered in this section of the chapter. This process and accompanying results are presented in the following seven sections that include:

- Site Description
- Data Input and Model Calibration
- HOV Lane Design Parameters and Their Selection
- Predicted I-210 Freeway Performance under 2004 Traffic Conditions
- Investigation of Added HOV Lane for 2+ Vehicles with Existing HOV Intermittent Partial Barriers
- Investigation of Modified HOV Lane for 2+ Vehicles with Increased HOV Intermittent Barriers

5.3.1 SITE DESCRIPTION

The southern California demonstration application site is the I-210 freeway in the westbound direction through Pasadena during the morning peak period. The study section extends from east of the I-210/I-605 interchange to west of the I210/SR134 interchange. The study section is 15.3 miles long and is divided into fifty-four subsections. The study duration was from 5:30 to 10:30 am and was divided into 20 15-minute time periods. There were a total of thirty-six freeway entries (one mainline entrance and thirty-five on-ramps) and thirty-three freeway exits (one mainline exit and thirty-two off-ramps).

The existing freeway cross-section consists of four basic mixed flow lanes with a limited-access full-time HOV lane. However there exists many auxiliary lanes and some subsections have as many as six mixed-flow lanes. All ramps are located on the right-side of the freeway but include both single-lane and two-lane ramps. A median HOV lane extended over almost the entire length of the freeway study section with an associated intermittent barrier. The freeway design features for each subsection along the study section is shown in Figure 5.17.

The freeway is heavily congested with congestion on a typical day extending from about 6 to 10 am. There are a number of bottlenecks along the study section with some causing queues to back into upstream bottlenecks. This study section is one of the more complex study sections because of the large number of auxiliary lanes, heavy ramp flows, numerous weaving sections, the special design of the HOV lane, and the heavy congestion with overlapping queues.

FREEWAY AND ARTERIAL DESIGN FEATURES

SUB SEC	NO. LNS	SSEC CAP	SSEC LENGTH	DESIGN SPEED	ORG DES	TRK FAC	SSEC GRAD	PCT TRK	PCT DES TRUCKS	SPECIAL RAMP	FF.SPD. ALT.RTE	CAP. ALT.RTE	ART TYPE	GRADE ALT.RTE	SUBSECTION LOCATION
1	4	8800.	2640.	70	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Study Begin to Start HOV
2	4	8400.	870.	70	O	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Start HOV to Vernon On
3	4	8400.	3750.	70	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Vernon On to Inwin Off
4	4	8400.	1488.	70		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Inwin off to Inwin on1
5	4	7200.	793.	70	O	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Irwin On1 to -Irwin On2
6	5	11000.	1500.	70	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Irwin On2 to 605 Off1s
7	5	11000.	1500.	70	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	SECOND PART OF SPLIT SS
8	5	11000.	2074.	70	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	THIRD PART OF SPLIT SS
9	4	8800.	1350.	70	D	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	605 Off1s-605 Off2n
10	4	8800.	2325.	70		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	605 Off2n-605 On1s
11	4	8800.	1063.	70	O	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	605 On1s-605 On2n
12	5	11000.	2474.	70	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	605 On2n to Buena Off
13	5	11000.	1050.	70	D	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Buena Off to Mount Off
14	5	11000.	425.	70	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	SECOND PART OF SPLIT SS
15	4	8800.	625.	70	D	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Mount Off to Buena On
16	4	8800.	1051.	70	O	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	SECOND PART OF SPLIT SS
17	4	8800.	1993.	70	O	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Buena On to Mount On
18	5	11000.	1630.	70	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Mount On to Myrtle Off
19	4	8800.	1500.	70	D	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Myrtle Off to Myrtle On
20	4	8800.	1238.	70	O	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	SECOND PART OF SPLIT SS
21	4	8800.	262.	70	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Myrtle On to Hunt Off
22	4	8800.	2204.	70	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	SECOND PART OF SPLIT SS
23	4	8800.	2640.	70		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Hunt Off - Hunt On
24	4	7400.	2912.	70	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Hunt On to Santa Off
25	4	8800.	1456.	70		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Santa Off to Santa On1n
26	4	8800.	962.	70	O	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Santa On1n - Santa On2s
27	4	8800.	3231.	70	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Santa On2 to Bald Off
28	4	8800.	1050.	70	D	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Bald Off to Bald On1
29	4	8800.	926.	70	O	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	SECOND PART OF SPLIT SS
30	4	8800.	124.	70	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Bald On1 to Bald On2

Figure 5.17 I-210 Freeway Design Features (Part 1)

FREEWAY AND ARTERIAL DESIGN FEATURES

SUB SEC	NO. LNS	SSEC CAP	SSEC LENGTH	DESIGN SPEED	ORG DES	TRK FAC	SSEC GRAD	PCT TRK	PCT DES TRUCKS	SPECIAL RAMP	FF.SPD. ALT.RTE	CAP. ALT.RTE	ART TYPE	GRADE ALT.RTE	SUBSECTION LOCATION
31	4	8800.	1051.	70	O	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	SECOND PART OF SPLIT SS
32	4	8575.	1955.	70	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Bald On2 to Mich Off
33	4	8800.	1350.	70		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Mich Off to Mich On
34	4	8800.	1318.	70	O	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Mich On to Rose On1
35	5	11000.	1006.	70	O	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Rose On1 to Rose On2
36	6	13200.	1088.	70	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Rose On2 - Sierra Off
37	5	11000.	1644.	70		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Sierra Off to Sierra On
38	6	13200.	1862.	70	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Sierra On to San G. Off
39	5	11000.	1393.	70	D	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	San G.Off to San G. On
40	5	11000.	1375.	70	O	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	SECOND PART OF SPLIT SS
41	5	10350.	100.	70	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	San G. On to Alt On
42	5	10350.	1313.	70	O	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	SECOND PART OF SPLIT SS
43	6	13200.	856.	70	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Alt On to Alt Off
44	5	10500.	3200.	70	D	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Alt Off to Hilll Off
45	5	11000.	2350.	70		0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Hill Off to Hill On
46	6	13200.	512.	70	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Hill On to Lake Off
47	5	11000.	767.	70	D	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Lake Off to Lake On
48	5	11000.	1279.	70	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	SECOND PART OF SPLIT SS
49	5	11000.	1279.	70	O	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	THIRD PART OF SPLIT SS
50	6	13200.	1185.	70	OD	0.95	0.0	5	50	YES	0.0	0.	GOOD	0.0	Lake On to Marg Off
51	6	13200.	600.	70	D	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	Marg Off to 210 Off
52	5	11000.	1720.	70	D	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	210 Off to 710 Off
53	4	8800.	2000.	70	D	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	710 Off- End of HOV Lane
54	4	8800.	2640.	70	OD	0.95	0.0	5	50	NO	0.0	0.	GOOD	0.0	End HOV Lane - Study End

Figure 5.17 I-210 Freeway Design Features (Part 2)

5.3.2 DATA INPUT AND MODEL CALIBRATION

Fortunately an earlier study had been undertaken of this freeway section in which the FREQ model was used in a supporting role in a more comprehensive application of the VISSIM model. This study and its results were published in 2004 in the Transportation Research Board's Record 1876. The research study was conducted by UC-Berkeley staff in cooperation with District 07 and sponsored by Caltrans. The data set described in this section of the chapter was obtained from this earlier study.

The required data for a simulation model primarily consists of supply-side data, demand-side data, and freeway performance data. The supply-side data includes the design features of the freeway and its ramps, and were presented in the previous section with the accompanying Figure 5.17.

The traffic demand data was based upon available 15-minute traffic counts for each entrance and exit along the freeway from 5:30 to 10:30 am when available. When such data was not available, traffic count estimates were made. The traffic count data was entered into the FREQ model and the model converted the traffic counts into an origin-destination demand table for each 15-minute time period. Unfortunately a comprehensive traffic count program could not be undertaken and traffic counts taken at different times from several studies were used. Another difficulty was that vehicle occupancy distribution data was not available for the various freeway entrances and a constant occupancy distribution was assumed for all freeway entries (88% single-occupant vehicles, 9% two-occupant vehicles, 3% three- occupant vehicles, and essentially no buses). These two deficiencies created some problems of uncertainty later in the calibration process.

Freeway performance data was obtained from mainline freeway detector stations and a field-measured speed contour map was constructed for several days for the calibration process. The field-measured speed contour maps were compared to the model- generated speed contour map to determine how well the model predicted existing freeway speed conditions. Prior to the calibration process, all input data was carefully checked for errors and compatibility.

In the calibration process model inputs, particularly capacities, were slightly adjusted in order for the model-generated speed contour map to more closely represent the field-measured speed contour map. There were several traffic and data problems that led to difficulties in the calibration process. Data for several off-ramps were not available and estimates were made as needed. Data errors were found in some of the on-ramp counts and data adjustments were required. Finally, traffic counts were obtained from different studies and not obtained in a comprehensive traffic count program. The final calibration investigation of the base existing conditions was acceptable for demonstration purposes but a comprehensive traffic count and occupancy distribution program would be required if serious thought is to be given to modeling HOV lane enhancements with accompanying ramp metering plan improvements. For more details on the data input and calibration process, the reader is referred to the initial application of the FREQ model to this site that was published in 2004 in the Transportation Research Board's Record 1876.

5.3.3 HOV LANE DESIGN PARAMETERS AND THEIR SELECTION

Unlike the I-580 freeway discussed in the previous section, the I-210 in District 07 already had a HOV lane so that the initial results are for the existing HOV lane design. Because of the uncertainty in the occupancy distribution and traffic counts available, special attention was given to extensive sensitivity investigations of these two HOV design parameters. A discussion of other design parameters is presented in the following portions of this section.

5.3.3.1 Number of HOV Lanes

The existing HOV design was a single HOV lane and consideration was not given to considering an additional HOV lane in these investigations.

5.3.3.2 HOV Cut-Off Limit

The existing HOV cut-off limit was for vehicles carrying 2+ persons and consideration was not given to changing these cut-off limits in these investigations. Part of the reason for not changing the HOV cut-off limit in these investigations is because the cut-off limit of 2+ vehicles is commonly used in District 07.

5.3.3.3 Length and Placement of HOV Lane

The existing HOV lane extended over the complete length of the freeway. Since congestion in the non-HOV lanes extended over the complete length of the freeway, the length and placement of the HOV lane was not changed in these investigations.

5.3.3.4 Time of HOV Operations

The existing HOV lane was in operation for 24-hours a day. Congestion occurred near the beginning of the study duration period and continued until almost the end of the study duration period. No data was available before or after the study duration period, so no change was made in the study duration period.

5.3.3.5 HOV Barriers

A set of intermittent barriers in the form of pavement markings was part of the existing HOV lane. In the initial set of investigations the current intermittent barriers were not modified. However the results of these initial results showed overloading of the HOV lane when vehicle occupancy distribution and/or growth factors were engaged. Therefore modifications were made in the second set of investigations in which the access to the HOV lane was reduced.

5.3.3.6 Vehicle Occupancy Distribution

The existing occupancy distribution used in the initial investigation assumed a distribution of 88% single-occupant vehicles, 9% vehicles with two persons, 3% vehicles with three or more persons, and essentially no buses. However the assumed occupancy distribution was based on little field data. Because of the uncertainties in the occupancy distribution and aware of how sensitive the results are to the occupancy distribution, an extensive set of sensitivity investigations were undertaken.

5.3.3.7 Anticipated Future Growth

The traffic counts used in the initial investigation in many cases were estimated. Because of the uncertainties in the traffic counts and aware of how sensitive the results are to the traffic counts, an extensive set of sensitivity investigations were undertaken.

5.3.4 PREDICTED I-210 FREEWAY PERFORMANCE UNDER 2004 TRAFFIC CONDITIONS

The predicted performance for the HOV lane only and the non-HOV lanes are presented and discussed in the following two portions of this section of the chapter.

5.3.4.1 HOV Lane Traffic Performance

The FREQ summary table of simulation results for the HOV lane is shown in Figure 5.18. The total travel time spent by all vehicles in the HOV was 1659 passenger-hours and their total travel mileage was 116,119 miles. The average speed in the HOV lane over the length of the study section was 70 mph over the study duration period and there was no congestion in the HOV lane.

5.3.4.2 Non-HOV Lane Traffic Performance

The FREQ summary table of simulation results for the non-HOV lanes is shown in Figure 5.19. The total travel time spent by all vehicles in the non- HOV lanes was 13,570 passenger-hours and their total travel mileage was 546,676 miles. The average speed in the non-HOV lanes over the length of the study section and the study duration time was 40.4 mph over the study duration period. Individual time slice average speeds over the length of the freeway began with speeds of 69 mph, gradually decreased to 28 mph during the middle of the study duration period, and then increased back to 69 mph at the end of the study duration period.

The FREQ queuing contour map for the non-HOV lanes is shown in Figure 5.20. Travel along the freeway is from left to right and extends over the 54 subsections. Time is shown on the vertical scale beginning at 5:30am at the top and continuing to 10:30am at the bottom. Locations of congestion (freeway queues) are shown as asterisks and bottlenecks are located at the downstream edge of the asterisks. Bottlenecks occur in subsections 05, 24, 32, and 42. The HOV intermittent barriers are shown at the top and bottom of the figures.

FREEWAY SUMMARY TABLE

SHORT TERM SIMULATION OF PRIORITY LANE

TIME SLICE	FREEWAY TRAVEL TIME VEH-HR	FREEWAY TRAVEL TIME PAS-HR	RAMP DELAY VEH-HR	RAMP DELAY PAS-HR	TOTAL FREEWAY TRAVEL TIME VEH-HR	TOTAL FREEWAY TRAVEL TIME PAS-HR	TOTAL TRAVEL DISTANCE VEH-MI	TOTAL TRAVEL DISTANCE PAS-MI	AVERAGE SPEED MPH	GASOLINE CONSUMED GALLONS	HYDROCARB EMISSIONS KILOGRAMS	CARBON MONOXIDE KILOGRAMS	NITROUS OXIDES KILOGRAMS	BEGIN TIME
1	33.	75.	0.	0.	33.	75.	2289.	5265.	70.0	126.	1.	9.	1.	5:30
2	36.	83.	0.	0.	36.	83.	2532.	5824.	70.0	139.	1.	10.	1.	5:45
3	40.	91.	0.	0.	40.	91.	2777.	6388.	70.0	153.	1.	11.	1.	6:00
4	42.	97.	0.	0.	42.	97.	2949.	6783.	70.0	162.	1.	12.	1.	6:15
5	43.	100.	0.	0.	43.	100.	3032.	6975.	70.0	167.	1.	12.	1.	6:30
6	40.	92.	0.	0.	40.	92.	2808.	6458.	70.0	154.	1.	11.	1.	6:45
7	41.	94.	0.	0.	41.	94.	2875.	6612.	70.0	158.	1.	12.	1.	7:00
8	42.	98.	0.	0.	42.	98.	2973.	6837.	70.0	163.	1.	12.	1.	7:15
9	41.	94.	0.	0.	41.	94.	2862.	6582.	70.0	157.	1.	12.	1.	7:30
10	36.	83.	0.	0.	36.	83.	2537.	5835.	70.0	140.	1.	10.	1.	7:45
11	41.	95.	0.	0.	41.	95.	2892.	6653.	70.0	159.	1.	12.	1.	8:00
12	38.	88.	0.	0.	38.	88.	2676.	6156.	70.0	147.	1.	11.	1.	8:15
13	36.	84.	0.	0.	36.	84.	2551.	5868.	70.0	140.	1.	10.	1.	8:30
14	34.	78.	0.	0.	34.	78.	2375.	5463.	70.0	131.	1.	10.	1.	8:45
15	32.	74.	0.	0.	32.	74.	2240.	5152.	70.0	123.	1.	9.	1.	9:00
16	30.	68.	0.	0.	30.	68.	2081.	4786.	70.0	114.	1.	8.	1.	9:15
17	32.	74.	0.	0.	32.	74.	2262.	5202.	70.0	124.	1.	9.	1.	9:30
18	28.	64.	0.	0.	28.	64.	1959.	4506.	70.0	108.	1.	8.	1.	9:45
19	27.	63.	0.	0.	27.	63.	1904.	4379.	70.0	105.	1.	8.	1.	10:00
20	27.	63.	0.	0.	27.	63.	1911.	4395.	70.0	105.	1.	8.	1.	10:15
TOTAL	721.	1659.	0.	0.	721.	1659.	50486.	116119.	70.0	2776.	17.	205.	17.	

Figure 5.18 I-210 Predicted HOV Lane Performance

FREEWAY SUMMARY TABLE
SHORT TERM SIMULATION OF NON-PRIORITY LANES

TIME SLICE	FREEWAY TRAVEL TIME VEH-HR	FREEWAY TRAVEL TIME PAS-HR	RAMP DELAY VEH-HR	RAMP DELAY PAS-HR	TOTAL FREEWAY TRAVEL TIME VEH-HR	TOTAL FREEWAY TRAVEL TIME PAS-HR	TOTAL TRAVEL DISTANCE VEH-MI	TOTAL TRAVEL DISTANCE PAS-MI	AVERAGE SPEED MPH	GASOLINE CONSUMED GALLONS	HYDROCARB EMISSIONS KILOGRAMS	CARBON MONOXIDE KILOGRAMS	NITROUS OXIDES KILOGRAMS	BEGIN TIME
1	317.	328.	0.	0.	317.	328.	21981.	22791.	69.4	1280.	7.	88.	8.	5:30
2	359.	372.	0.	0.	359.	372.	24333.	25232.	67.8	1381.	8.	96.	9.	5:45
3	428.	447.	4.	4.	432.	451.	26556.	27571.	62.0	1478.	9.	104.	10.	6:00
4	466.	484.	4.	4.	470.	489.	27210.	28317.	58.4	1509.	9.	107.	10.	6:15
5	574.	598.	9.	11.	583.	608.	27472.	28704.	47.9	1530.	10.	111.	10.	6:30
6	664.	692.	18.	20.	682.	713.	27322.	28611.	41.1	1537.	10.	113.	10.	6:45
7	752.	784.	15.	18.	768.	802.	27497.	28821.	36.5	1554.	11.	115.	11.	7:00
8	874.	910.	13.	15.	887.	925.	27595.	28942.	31.6	1579.	11.	118.	11.	7:15
9	953.	994.	9.	11.	962.	1005.	28462.	29886.	29.9	1589.	11.	121.	11.	7:30
10	988.	1032.	3.	4.	991.	1036.	27977.	29428.	28.3	1581.	12.	121.	11.	7:45
11	952.	989.	0.	0.	952.	989.	28528.	29838.	30.0	1590.	12.	123.	11.	8:00
12	973.	1013.	0.	0.	973.	1013.	28389.	29750.	29.2	1583.	12.	124.	11.	8:15
13	941.	980.	0.	0.	941.	980.	28335.	29672.	30.1	1571.	11.	123.	11.	8:30
14	864.	901.	0.	0.	864.	901.	27515.	28823.	31.8	1526.	11.	119.	11.	8:45
15	754.	786.	0.	0.	754.	786.	27117.	28408.	36.0	1485.	10.	114.	10.	9:00
16	611.	639.	1.	1.	612.	640.	26452.	27757.	43.3	1432.	9.	107.	10.	9:15
17	491.	514.	1.	1.	492.	514.	25678.	26902.	52.2	1420.	9.	103.	10.	9:30
18	384.	403.	1.	1.	385.	404.	23361.	24557.	60.8	1326.	8.	93.	9.	9:45
19	292.	306.	1.	1.	293.	307.	20364.	21363.	69.7	1192.	7.	82.	8.	10:00
20	291.	306.	0.	0.	291.	306.	20319.	21304.	69.7	1189.	7.	82.	8.	10:15
TOTAL	12928.	13480.	78.	90.	13006.	13570.	522464.	546676.	40.4	29332.	193.	2163.	200.	

Figure 5.19 I-210 Predicted Non-HOV Lane Performance

```
CONTOUR DIAGRAM OF
QUEUE LENGTH                NON-PRIORITY LANE(S)
AFTER   (DAY+1)

        TIME                                                                                                        BEGIN
        SLICE .....................................................................................................  TIME
              .       P ============           ===================       ==========           =================.
            1 .                                                                                                   . -  5:30
            2 .                                                                                                   . -  5:45
            3 .                                                                                                   . -  6:00
            4 .                 **                                                         *************          . -  6:15
            5 . ******************                                               ***********************          . -  6:30
            6 .*******************                                          ****************************          . -  6:45
            7 .*******************                                  ************************************          . -  7:00
            8 .*******************                         *********************************************          . -  7:15
            9 .*******************                  ****************************************************          . -  7:30
           10 .                               **********************************************************          . -  7:45
           11 .                            *************************************************************          . -  8:00
           12 .                              ***********************************************************          . -  8:15
           13 .                                   ******************************************************          . -  8:30
           14 .                                             ********************************************          . -  8:45
           15 .                                                       **********************************          . -  9:00
           16 .                                                                         ****************          . -  9:15
           17 .                                                                                     ****          . -  9:30
           18 .                                                                                                   . -  9:45
           19 .                                                                                                   . - 10:00
           20 .                                                                                                   . - 10:15
              .       P ============           ===================       ==========           =================.
              .....................................................................................................
               :      : :     :   : :   :   :    :  :     :  :     :  :: :  :    :   :   :  ::    :      :      :
               01     0203    04  0506  07  08   09 10    11 12    13  1516 17   18  19  20  22   23     24     25
```

```
CONTOUR DIAGRAM OF
QUEUE LENGTH                NON-PRIORITY LANE(S)
AFTER   (DAY+1)

        TIME                                                                                                        BEGIN
        SLICE .....................................................................................................  TIME
              .============       ==========================        =================       =========    P      .
            1 .                                                                                                   . -  5:30
            2 .                                                                                                   . -  5:45
            3 .                 ***                                                                               . -  6:00
            4 .                  **                                                                               . -  6:15
            5 .            ********                                                                               . -  6:30
            6 .        ************                                                                               . -  6:45
            7 .    ****************                                                                               . -  7:00
            8 .********************                                                                               . -  7:15
            9 .   *****************                     **********                                                . -  7:30
           10 .         ***********                ***************                                                . -  7:45
           11 .       *************             ******************                                                . -  8:00
           12 .      **************         **********************                                                . -  8:15
           13 .   *****************           ********************                                                . -  8:30
           14 . *******************               ****************                                                . -  8:45
           15 . *******************                      *********                                                . -  9:00
           16 .   *****************                              *                                                . -  9:15
           17 .   *****************                                                                               . -  9:30
           18 .                                                                                                   . -  9:45
           19 .                                                                                                   . - 10:00
           20 .                                                                                                   . - 10:15
              .============       ==========================        =================       =========    P      .
              .....................................................................................................
                : :       :  : ::  :   :  :  : :  :   :    :  : ::  : :      :     :: :  :  :  ::   :    :
                2627      28 29 31 32   33 34 3536 37  38   39 40  42 4344    45     4748 49 50  52  53   54

         P  PROPOSED LOCATION FOR THE PRIORITY LANE(S)  P   BARRIER EXTENDS OVER LENGTH OF ==== SYMBOL

         BLANK DENOTES MOVING TRAFFIC.  ASTERISK DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION.
         M  DENOTES QUEUED VEHICLES DUE TO MERGING.  B  DENOTES QUEUED VEHICLES DUE TO MAINLINE CONGESTION AND
         MERGING.   (WHEN BOTH QUEUES EXIST, LENGTH OF DISPLAY REPRESENTS MAINLINE CONGESTION.)
```

Figure 5.20 Non-HOV Lane Congestion Pattern

5.3.5 INVESTIGATION OF ADDED HOV LANE FOR 2+ VEHICLES WITH EXISTING HOV INTERMITTENT BARRIERS

As discussed in the previous section, the following set of investigations of an added HOV lane were initially assumed to be:

- Single added HOV lane
- HOV cut-off limit of 2+
- HOV lane over the entire study section
- Peak period operations only
- Existing intermittent HOV lane barrier
- Assumed vehicle occupancy distribution
- 2004 freeway demand level

Further investigations of the first five assumptions will be undertaken if deemed desirable and sensitivity analysis will be undertaken of vehicle occupancy distribution and freeway demand level. The percent of vehicles carrying 2+ persons will vary from 4% to 36% with an initial value of 12%. The freeway demand level will vary from 0.95 to 1.10 with an initial value of 1.00 representing the year 2004 freeway demand level.

5.3.5.1 Sensitivity Analysis of Vehicle Occupancy Distribution and Anticipated Future Growth

As mentioned earlier, the vehicle occupancy distribution and anticipated future growth have a significant impact on the success of an added HOV lane operation. Thus a sensitivity analysis was undertaken in which the percent of vehicles carrying 2+ persons will vary from 4% to 36% in 4% intervals (with 12% 2+ vehicles representing base conditions). The freeway demand level was also varied from 0.95 to 1.10 (in steps of 0.05) with an initial value of 1.00 representing the year 2004 freeway demand level.

The results of these sensitivity analysis investigations are summarized in Figures 5.21, 5.22, 5.23, and 5.24 with each figure representing a different freeway demand level (0.95, 1.00, 1.05, and 1.10). The rows in each figure represent measures of performances while the vertical columns represent the percent vehicles carry 2+ vehicles ranging from 4% to 36%. The results for each of the four freeway demand levels are discussed in the following four sections.

The calculation of differences and percent differences in measures of performance are based upon the results obtained in the base case existing HOV conditions which were with a growth factor of 1.00 and 12% 2+ vehicles. The results for the base case is shown in Figure 5.22 in the vertical column marked “GF = 1.00, 2+ HOV = 12%”.

5.3.5.2 Impact of 2+ HOV Lane with 0.95 Freeway Demand Level

Figure 5.21 presents the impacts of a 2+ HOV lane with a freeway demand level of 0.95 and with a varying percent of vehicles carrying 2+ persons from 4% to 36%. Special attention is given to six performance measures that are shown in bold type. There were four types of HOV lane operations encountered depending upon the 2+% HOV percentage.

The vertical column “GF = 0.95, 2+ HOV = 12%” compares the predicted performances with the only change being in growth factor. These results shown that if traffic demands decrease by 5%, (1) total passenger-times, total passenger-miles, fuel consumption, and vehicle emissions decrease, (2) the average speed in the HOV lane does not change, and (3) the speed in the non-HOV lanes increases by 10.8 mph.

If in addition to the decrease in traffic demands by 5%, a decrease in 2+ % HOV vehicles (1) increases total passenger-hours and vehicle emissions, (2) reduces total passenger-miles, fuel consumption, and non-HOV lane speeds, and (3) HOV lane speeds are unchanged.

If in addition to the decrease in traffic demands by 5%, an increase in 2+ % HOV vehicles to 16% results in (1) increases total passenger-miles and non-HOV lane speeds and (2) reduces total passenger-hours, fuel consumption, vehicle emissions, and HOV lane speeds. This is a boundary condition with light congestion beginning to occur over a portion of the HOV lane.

If there is an increase in 2+% HOV vehicles to 20% or more combined with the 5% growth in traffic demand, congestion occurs in the HOV lane and queues from the HOV lane extend into the non-HOV lanes.

5.3.5.3 Impact of 2+ HOV Lane with 1.00 Freeway Growth Level

Figure 5.22 presents the impacts of a 2+ HOV lane with a freeway demand level of 1.00 and with a varying percent of vehicles carrying 2+ persons from 4% to 36%. Special attention will be given to six performance measures that are shown in bold type. There were four types of HOV lane operations encountered depending upon the 2+% HOV percentage.

The vertical column "GF = 1.00, 2+ HOV = 12%" is the base case and obvious since there is no change in either growth factor nor % 2+ HOV vehicles, there is no change in predicted performance measures

A decrease in 2+ % HOV vehicles (1) increases total passenger-hours and vehicle emissions, (2) reduces total passenger-miles, fuel consumption, and non-HOV lane speeds, and (3) no change in HOV lane average speed.

An increase in 2+ % HOV vehicles to 16% (1) increases total passenger-miles, fuel consumption, and non-HOV lane speeds and (2) reduces total passenger-hours and HOV lane speeds. This is a boundary condition with a light congestion beginning to occur over a portion of the HOV lane and little difference between HOV lane and non-HOV lane average speeds.

If there is an increase in 2+% HOV vehicles to 20% or more, congestion occurs in the HOV lane and queues from the HOV lane extend into the non-HOV lanes.

5.3.5.4 Impact of 2+ HOV Lane with 1.05 Freeway Growth Level

Figure 5.23 presents the impacts of a 2+ HOV lane with a freeway demand level of 1.05 and with a varying percent of vehicles carrying 2+ persons from 4% to 36%. Special attention will be given to six performance measures that are shown in bold type. There were four types of HOV lane operations encountered depending upon the 2+% HOV percentage.

The vertical column "GF = 1.05, 2+ HOV = 12%" compares the predicted performances with the only change being in growth factor. These results shown that if traffic demands increase by 5%, (1) HOV lane and non-HOV lane average speeds decrease and (2) total passenger-time, total passenger-miles, fuel consumption, and vehicle emissions increase.

If in addition to the increase in traffic demands by 5%, a decrease in 2+ % HOV vehicles (1) increases total passenger-hours and HOV lane average speeds and (2) reduces total passenger-miles, fuel consumption, vehicle emissions, and non-HOV lane speeds.

If in addition to the increase in traffic demands by 5%, an increase in 2+ % HOV vehicles to 16% results in (1) increases total passenger-hours, total passenger-miles, fuel consumption, and non-HOV lane speeds and (2) reduces HOV lane average speeds. This is a boundary condition with moderate congestion beginning to occur over a portion of the HOV lane with the average speed in the non-HOV lanes approaching the average speed in the HOV lane.

If there is an increase in 2+% HOV vehicles to 20% or more combined with the 5% growth in traffic demand, congestion occurs in the HOV lane and queues from the HOV lane extend into the non-HOV lanes.

5.3.5.5 Impact of 2+ HOV Lane with 1.10 Freeway Growth Level

Figure 5.24 presents the impacts of a 2+ HOV lane with a freeway demand level of 1.10 and with a varying percent of vehicles carrying 2+ persons from 4% to 36%. Special attention will be given to six performance measures that are shown in bold type. There were four types of HOV lane operations encountered depending upon the 2+% HOV percentage.

The vertical column "GF = 1.10, 2+ HOV = 12%" compares the predicted performances with the only change being in growth factor. These results shown that if traffic demands increase by 10%, (1) HOV lane and non-HOV lane average speeds decrease and (2) total passenger-time, total passenger-miles, fuel consumption, and vehicle emissions increase.

If in addition to the increase in traffic demands by 5%, a decrease in 2+ % HOV vehicles (1) increases total passenger-hours, vehicle emissions, and HOV lane average speeds and (2) reduces total passenger-miles, fuel consumption, and non-HOV lane speeds.

If in addition to the increase in traffic demands by 5%, an increase in 2+ % HOV vehicles to 16% results in (1) increases total passenger-hours, total passenger-miles, fuel consumption, and vehicle emissions and (2) reduces HOV lane and non-HOV lane average speeds. This is a boundary condition with moderate congestion beginning to occur over a portion of the HOV lane with the average speed in the non-HOV lanes approximately equal to the average speed in the HOV lane.

If there is an increase in 2+% HOV vehicles to 20% or more combined with the 5% growth in traffic demand, congestion occurs in the HOV lane and queues from the HOV lane extend into the non-HOV lanes.

5.3.5.6 Overall Summary of Results on Each Measure of Performance

Sensitivity of results presented on a percentage basis (in most cases) for sixteen selected measures of performance is shown in Figures 5.25A, 5.25B, 5.25C, and 5.25D. Recall that the base conditions assume that 12% of the vehicles carry 2+ persons and the growth factor is 1.00. The indicated percentage changes for each measure of performance applied the base case results for the calculations. Only the results when the 2+ HOV is 16% or less are discussed in the following paragraphs since when 2+ HOV percentage is greater than 16%, the HOV lane is congested. At higher 2+ HOV percentages, the queue from the HOV lane congestion extends out of the HOV lane section. The average speeds in the non-HOV lanes are approximately the same as the average speeds in the HOV lane.

Comments on each of the sixteen selected measures of performance are presented in the following sixteen paragraphs.

The percent change in total time and delay in passenger-hours are negative under lower traffic demand levels. Conversely, the percentage changes are the positive under higher demand levels. Increases in total time and delay are not necessarily bad if they are accompanied by increases in total passenger travel (Figure 5.25A). This will be discussed later.

The percent changes in freeway travel in passenger-miles are positive under higher traffic demand levels combined with higher percentages of 2+ HOV vehicles. The percent changes are negative under low traffic demand levels and under low percentages of 2+ % HOV vehicles. The negative percentages indicate that fewer people are being served during the peak period (Figure 5.25A)

The percent change in overall average HOV vehicle speeds in mph are unchanged under lower traffic demand levels combined with lower percentage of 2+ % HOV vehicles. Average speeds in the HOV lane are reduced as traffic demands increased and percentage of 2+ % HOV vehicles increase (Figure 5.25A)

The percent change in overall average non-HOV vehicle speeds in mph increase under lower traffic demand levels combined with higher percentage of 2+ % HOV vehicles. Conversely, average non-HOV lane speeds are reduced as demand levels increase (Figure 5.25A).

The percent change in total fuel consumed increased with higher traffic demands combined with higher percentage of 2+ HOV vehicles. The percent change decreased under lower traffic demand levels (Figure 5.25B).

The percentage change in total emissions pretty much followed the pattern of percent changes in total fuel consumed. That is, total emissions increased with higher traffic demands combined with higher percentage of 2+ HOV vehicles and decreased under higher traffic demand levels (Figure 5.25B).

Another set of results that is often helpful is the level of flow in the HOV lane. Low flows in the HOV lane indicate that the added HOV lane is not being effectively used and also non-HOV users particularly may be concerned about this under-utilization. Obviously high flows approaching the capacity of the HOV lane are of concern because of the poor level of service being provided to HOV users and also because of not having available capacity for future HOV growth. Too high a demand in the HOV lane was a problem in these sensitivity investigations. Investigations at lower 2+ HOV percentages combined with lower levels of traffic demands resulted in low flows in the HOV lane. Investigations at higher 2+ HOV percentages combined with higher levels of traffic demands resulted in congestion in the HOV lane. The base condition resulted in flow levels that generally were in the range of 500 to 1300 vehicles per hour (Figure 5.25B).

Another set of results that is often informative is the level of freeway congestion in the HOV lane and the non-HOV lanes. For each cell in the final table of Figure 5.25B, there is a code of two letters indicating the level of freeway congestion in the HOV lane and in the non-HOV lanes. The following letters are used to indicate the level of congestion: no congestion (N), light congestion (L), moderate congestion (M), and heavy congestion (H). The designation of light, moderate, and heavy congestion is determined qualitatively for comparison purposes. For the HOV lane, there is no congestion in this lane until the 2+ % HOV vehicles approach 16% and the level of congestion changes from little to moderate as the growth factor increases. For the non-HOV lanes, there is always heavy congestion in these lanes except under lower growth factors combined with higher 2+ % HOV vehicles when the congestion level is classified as being moderate.

The four tables contained in Figure 5.25C provide total quantities expended in fuel consumption, vehicle emissions, passenger time, and passenger travel. These total quantities can be misleading in assessing the implementation of HOV lanes. For example, the total passenger-miles traveled within the study section and study duration period varied between investigations. Hence total fuel consumption, vehicle emissions, and passenger-hours would be expected to vary due to different levels of total passenger-miles of travel as well as due to the appropriateness of the HOV lane design. The total quantities shown in Figure 5.25C were used to create the first three tables contained in Figure 5.25D.

Average fuel consumption rates (passenger-miles per gallon) are displayed in the first table of Figure 5.25D. The percentage of 2+ HOV vehicles is shown to be a much more important influence on fuel consumption rates than growth factor. Fuel consumption rates continue to improve (increase) as percentage of 2+ HOV vehicles increase until the HOV lane begins to be seriously congested. It is interesting to note that if the traffic demands increase over existing conditions (growth factor = 1.00), the average fuel consumption rates do not change appreciatively. It is also interesting to note that if the percentage of 2+ HOV vehicles increases up to 16% (from 12%), the average fuel consumption rate improves (increases).

Average vehicle emission rates (passenger-miles per kilogram) are displayed in the second table of Figure 5.25D. It is interesting to note that if the traffic demands increase over existing conditions (growth factor = 1.00), the average vehicle emission rates are slightly reduced. It is also interesting to note that if the percentage of 2+ HOV vehicles increases up to 16% (from 12%), the average vehicle emission rate improves (increases).

Average vehicle speeds (miles per hour) are displayed in the third table of Figure 5.25D. Another way of looking at this rate is in terms of passenger-miles traveled per hour of time. Increases in traffic demand levels combined with lower percentages of 2+ HOV vehicles reduce this rate. Increases in the percentage of 2+ HOV vehicles from 12% (the base case) to 16% results in higher rates when combined with growth factors of 0.95 to 1.05.

The final table in Figure 5.25D displays the differential average speeds between the HOV lane and the non-HOV lanes for various traffic demand levels and percentage of 2+ HOV vehicles. The most important observation from this table is that as the percentage of 2+ HOV vehicles increase above the base case (12%), the differential speed decreases. With low differential speeds between lanes, there is little encouragement for HOV vehicles to use the HOV lanes nor for non-HOV users to become HOV users.

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE (GF=0.95)									FILE=I210WA-PB2-FINAL	
MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 0.95 2+ HOV = 4%	GF = 0.95 2+ HOV = 8%	GF = 0.95 2+ HOV = 12%	GF = 0.95 2+ HOV = 16%	GF = 0.95 2+ HOV = 20%	GF = 0.95 2+ HOV = 24%	GF = 0.95 2+ HOV = 28%	GF = 0.95 2+ HOV = 32%	GF = 0.95 2+ HOV = 36%
FREEWAY	EXISTING HOV	15139	15139	15139	15139					
TRAVEL TIME	MODIFIED HOV	13743	12672	11758	11299	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**
PASS-HRS	DIFFERENCE	-1396	-2467	-3381	-3840					
	% DIFFERENCE	-9.2	-16.3	-22.3	-25.4					
RAMP	EXISTING HOV	90	90	90	90					
DELAY	MODIFIED HOV	175	44	0	0	**OUT**	**OUT**	**OUT**	**OUT**	**OUT**
PASS-HRS	DIFFERENCE	85	-46	-90	-90					
	% DIFFERENCE	94.4	-51.1	-100.0	-100.0					
TOTAL	EXISTING HOV	15229	15229	15229	15229					
TIME & DELAY	MODIFIED HOV	13918	12716	11758	11299	**OF**	**OF**	**OF**	**OF**	**OF**
PASS-HRS	DIFFERENCE	**-1311**	**-2513**	**-3471**	**-3930**					
	% DIFFERENCE	-8.6	-16.5	-22.8	-25.8					
FREEWAY	EXISTING HOV	662795	662795	662795	662795					
TRAVEL	MODIFIED HOV	570974	603060	632511	661633	**HOV**	**HOV**	**HOV**	**HOV**	**HOV**
PASS-MILES	DIFFERENCE	**-91821**	**-59735**	**-30284**	**-1162**					
	% DIFFERENCE	-13.9	-9.0	-4.6	-0.2					
HOV LANE	EXISTING HOV	70.0	70.0	70.0	70.0					
AVG SPEED	MODIFIED HOV	70.0	70.0	70.0	64.3	**LANE**	**LANE**	**LANE**	**LANE**	**LANE**
MPH	DIFFERENCE	**0.0**	**0.0**	**0.0**	**-5.7**					
	% DIFFERENCE	0.0	0.0	0.0	-8.1					
NON-HOV LANES	EXISTING HOV	40.4	40.4	40.4	40.4					
AVG SPEED	MODIFIED HOV	40.4	45.2	51.2	57.0					
MPH	DIFFERENCE	**0.0**	**4.8**	**10.8**	**16.6**					
	% DIFFERENCE	0.0	11.9	26.7	41.1					
TOTAL FUEL	EXISTING HOV	32108	32108	32108	32108					
CONSUMED	MODIFIED HOV	30394	30606	30748	30746	**DUE**	**DUE**	**DUE**	**DUE**	**DUE**
GALLONS	DIFFERENCE	**-1714**	**-1502**	**-1360**	**-1362**					
	% DIFFERENCE	-5.3	-4.7	-4.2	-4.2					
EMFAC2002	EXISTING HOV	210	210	210	210					
HC EMISSIONS	MODIFIED HOV	199	194	191	187	**TO**	**TO**	**TO**	**TO**	**TO**
KILOGRAMS	DIFFERENCE	-11	-16	-19	-23					
	% DIFFERENCE	-5.2	-7.6	-9.0	-11.0					
EMFAC2002	EXISTING HOV	2369	2369	2369	2369					
CO EMISSIONS	MODIFIED HOV	2251	2224	2203	2186	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**
KILOGRAMS	DIFFERENCE	-118	-145	-166	-183					
	% DIFFERENCE	-5.0	-6.1	-7.0	-7.7					
EMFAC2002	EXISTING HOV	217	217	217	217					
NO EMISSIONS	MODIFIED HOV	207	206	206	204	**IN**	**IN**	**IN**	**IN**	**IN**
KILOGRAMS	DIFFERENCE	-10	-11	-11	-13					
	% DIFFERENCE	-4.6	-5.1	-5.1	-6.0					
EMFAC2002	EXISTING HOV	2796	2796	2796	2796					
TOTAL EMISSION	MODIFIED HOV	2657	2624	2600	2577	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**
KILOGRAMS	DIFFERENCE	**-139**	**-172**	**-196**	**-219**					
	% DIFFERENCE	-5.0	-6.2	-7.0	-7.8					

Figure 5.21 Effect of Demand Growth and 2+ Vehicle Percentages on Performance of Partial Barrier HOV Lane (GF=0.95)

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE (GF=1.00)									FILE=I210WA-PB2-FINAL	
MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 1.00 2+ HOV = 4%	GF = 1.00 2+ HOV = 8%	GF = 1.00 2+ HOV = 12%	GF = 1.00 2+ HOV = 16%	GF = 1.00 2+ HOV = 20%	GF = 1.00 2+ HOV = 24%	GF = 1.00 2+ HOV = 28%	GF = 1.00 2+ HOV = 32%	GF = 1.00 2+ HOV = 36%
FREEWAY	EXISTING HOV	15139	15139	15139	15139					
TRAVEL TIME	MODIFIED HOV	18356	16708	15139	14640	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**
PASS-HRS	DIFFERENCE	3217	1569	0	-499					
	% DIFFERENCE	21.2	10.4	0.0	-3.3					
RAMP	EXISTING HOV	90	90	90	90					
DELAY	MODIFIED HOV	438	251	90	34	**OUT**	**OUT**	**OUT**	**OUT**	**OUT**
PASS-HRS	DIFFERENCE	348	161	0	-56					
	% DIFFERENCE	386.7	178.9	0.0	-62.2					
TOTAL	EXISTING HOV	15229	15229	15229	15229					
TIME & DELAY	MODIFIED HOV	18794	16959	15229	14674	**OF**	**OF**	**OF**	**OF**	**OF**
PASS-HRS	DIFFERENCE	**3565**	**1730**	**0**	**-555**					
	% DIFFERENCE	23.4	11.4	0.0	-3.6					
FREEWAY	EXISTING HOV	570450	598648	662795	655043					
TRAVEL	MODIFIED HOV	587154	629110	662795	694547	**HOV**	**HOV**	**HOV**	**HOV**	**HOV**
PASS-MILES	DIFFERENCE	**16704**	**30462**	**0**	**39504**					
	% DIFFERENCE	2.9	5.1	0.0	6.0					
HOV LANE	EXISTING HOV	70.0	70.0	70.0	70.0					
AVG SPEED	MODIFIED HOV	70.0	70.0	70.0	52.2	**LANE**	**LANE**	**LANE**	**LANE**	**LANE**
MPH	DIFFERENCE	**0.0**	**0.0**	**0.0**	**-17.8**					
	% DIFFERENCE	0.0	0.0	0.0	-25.4					
NON-HOV LANES	EXISTING HOV	40.4	40.4	40.4	40.4					
AVG SPEED	MODIFIED HOV	30.8	35.3	40.4	46.1					
MPH	DIFFERENCE	**-9.6**	**-5.1**	**0.0**	**5.7**					
	% DIFFERENCE	-23.8	-12.6	0.0	14.1					
TOTAL FUEL	EXISTING HOV	32108	32108	32108	32108					
CONSUMED	MODIFIED HOV	31791	32078	32108	32180	**DUE**	**DUE**	**DUE**	**DUE**	**DUE**
GALLONS	DIFFERENCE	**-317**	**-30**	**0**	**72**					
	% DIFFERENCE	-1.0	-0.1	0.0	0.2					
EMFAC2002	EXISTING HOV	210	210	210	210					
HC EMISSIONS	MODIFIED HOV	227	219	210	205	**TO**	**TO**	**TO**	**TO**	**TO**
KILOGRAMS	DIFFERENCE	17	9	0	-5					
	% DIFFERENCE	8.1	4.3	0.0	-2.4					
EMFAC2002	EXISTING HOV	2369	2369	2369	2369					
CO EMISSIONS	MODIFIED HOV	2436	2412	2369	2342	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**
KILOGRAMS	DIFFERENCE	67	43	0	-27					
	% DIFFERENCE	2.8	1.8	0.0	-1.1					
EMFAC2002	EXISTING HOV	217	217	217	217					
NO EMISSIONS	MODIFIED HOV	218	218	217	216	**IN**	**IN**	**IN**	**IN**	**IN**
KILOGRAMS	DIFFERENCE	1	1	0	-1					
	% DIFFERENCE	0.5	0.5	0.0	-0.5					
EMFAC2002	EXISTING HOV	2796	2796	2796	2796					
TOTAL EMISSION	MODIFIED HOV	2881	2849	2796	2763	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**
KILOGRAMS	DIFFERENCE	**85**	**53**	**0**	**-33**					
	% DIFFERENCE	3.0	1.9	0.0	-1.2					

Figure 5.22 Effect of Demand Growth and 2+ Vehicle Percentages on Performance of Partial Barrier HOV Lane (GF=1.00)

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE (GF=1.05) FILE=I210WA-PB2-FINAL

MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 1.05 2+ HOV = 4%	GF = 1.05 2+ HOV = 8%	GF = 1.05 2+ HOV = 12%	GF = 1.05 2+ HOV = 16%	GF = 1.05 2+ HOV = 20%	GF = 1.05 2+ HOV = 24%	GF = 1.05 2+ HOV = 28%	GF = 1.05 2+ HOV = 32%	GF = 1.05 2+ HOV = 36%
FREEWAY	EXISTING HOV	15139	15139	15139	15139					
TRAVEL TIME	MODIFIED HOV	20132	19637	18814	19642	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**
PASS-HRS	DIFFERENCE	4993	4498	3675	4503					
	% DIFFERENCE	33.0	29.7	24.3	29.7					
RAMP	EXISTING HOV	90	90	90	90					
DELAY	MODIFIED HOV	1067	640	358	222	**OUT**	**OUT**	**OUT**	**OUT**	**OUT**
PASS-HRS	DIFFERENCE	977	550	268	132					
	% DIFFERENCE	1085.6	611.1	297.8	146.7					
TOTAL	EXISTING HOV	15229	15229	15229	15229					
TIME & DELAY	MODIFIED HOV	21199	20277	19172	19864	**OF**	**OF**	**OF**	**OF**	**OF**
PASS-HRS	DIFFERENCE	**5970**	**5048**	**3943**	**4635**					
	% DIFFERENCE	39.2	33.1	25.9	30.4					
FREEWAY	EXISTING HOV	662795	662795	662795	662795					
TRAVEL	MODIFIED HOV	584171	638474	684981	725324	**HOV**	**HOV**	**HOV**	**HOV**	**HOV**
PASS-MILES	DIFFERENCE	**-78624**	**-24321**	**22186**	**62529**					
	% DIFFERENCE	-11.9	-3.7	3.3	9.4					
HOV LANE	EXISTING HOV	70.0	70.0	70.0	70.0					
AVG SPEED	MODIFIED HOV	70.0	70.0	69.8	39.4	**LANE**	**LANE**	**LANE**	**LANE**	**LANE**
MPH	DIFFERENCE	**0.0**	**0.0**	**-0.2**	**-30.6**					
	% DIFFERENCE	0.0	0.0	-0.3	-43.7					
NON-HOV LANES	EXISTING HOV	40.4	40.4	40.4	40.4					
AVG SPEED	MODIFIED HOV	27.8	30.1	32.8	36.1					
MPH	DIFFERENCE	**-12.6**	**-10.3**	**-7.6**	**-4.3**					
	% DIFFERENCE	-31.2	-25.5	-18.8	-10.6					
TOTAL FUEL	EXISTING HOV	32108	32108	32108	32108					
CONSUMED	MODIFIED HOV	32376	32989	33458	33728	**DUE**	**DUE**	**DUE**	**DUE**	**DUE**
GALLONS	DIFFERENCE	**268**	**881**	**1350**	**1620**					
	% DIFFERENCE	0.8	2.7	4.2	5.0					
EMFAC2002	EXISTING HOV	210	210	210	210					
HC EMISSIONS	MODIFIED HOV	241	237	233	231	**TO**	**TO**	**TO**	**TO**	**TO**
KILOGRAMS	DIFFERENCE	31	27	23	21					
	% DIFFERENCE	14.8	12.9	11.0	10.0					
EMFAC2002	EXISTING HOV	2369	2369	2369	2369					
CO EMISSIONS	MODIFIED HOV	2496	2529	2534	2540	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**
KILOGRAMS	DIFFERENCE	127	160	165	171					
	% DIFFERENCE	5.4	6.8	7.0	7.2					
EMFAC2002	EXISTING HOV	217	217	217	217					
NO EMISSIONS	MODIFIED HOV	221	225	227	228	**IN**	**IN**	**IN**	**IN**	**IN**
KILOGRAMS	DIFFERENCE	4	8	10	11					
	% DIFFERENCE	1.8	3.7	4.6	5.1					
EMFAC2002	EXISTING HOV	2796	2796	2796	2796					
TOTAL EMISSION	MODIFIED HOV	2958	2991	2994	2999	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**
KILOGRAMS	DIFFERENCE	**162**	**195**	**198**	**203**					
	% DIFFERENCE	5.8	7.0	7.1	7.3					

Figure 5.23 Effect of Demand Growth and 2+ Vehicle Percentages on Performance of Partial Barrier HOV Lane (GF=1.05)

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE (GF=1.10) FILE=I210WA-PB2-FINAL

MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 1.10 2+ HOV = 4%	GF = 1.10 2+ HOV = 8%	GF = 1.10 2+ HOV = 12%	GF = 1.10 2+ HOV = 16%	GF = 1.10 2+ HOV = 20%	GF = 1.10 2+ HOV = 24%	GF = 1.10 2+ HOV = 28%	GF = 1.10 2+ HOV = 32%	GF = 1.10 2+ HOV = 36%
FREEWAY	EXISTING HOV	15139	15139	15139	15139					
TRAVEL TIME	MODIFIED HOV	21277	21143	17177	24695	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**
PASS-HRS	DIFFERENCE	6138	6004	2038	9556					
	% DIFFERENCE	40.5	39.7	13.5	63.1					
RAMP	EXISTING HOV	90	90	90	90					
DELAY	MODIFIED HOV	1634	1199	777	739	**OUT**	**OUT**	**OUT**	**OUT**	**OUT**
PASS-HRS	DIFFERENCE	1544	1109	687	649					
	% DIFFERENCE	1715.6	1232.2	763.3	721.1					
TOTAL	EXISTING HOV	15229	15229	15229	15229					
TIME & DELAY	MODIFIED HOV	22911	22342	17954	25434	**OF**	**OF**	**OF**	**OF**	**OF**
PASS-HRS	DIFFERENCE	**7682**	**7113**	**2725**	**10205**					
	% DIFFERENCE	50.4	46.7	17.9	67.0					
FREEWAY	EXISTING HOV	662795	662795	662795	662795					
TRAVEL	MODIFIED HOV	585539	640751	689346	736759	**HOV**	**HOV**	**HOV**	**HOV**	**HOV**
PASS-MILES	DIFFERENCE	**-77256**	**-22044**	**26551**	**73964**					
	% DIFFERENCE	-11.7	-3.3	4.0	11.2					
HOV LANE	EXISTING HOV	70.0	70.0	70.0	70.0					
AVG SPEED	MODIFIED HOV	70.0	70.0	69.5	29.9	**LANE**	**LANE**	**LANE**	**LANE**	**LANE**
MPH	DIFFERENCE	**0.0**	**0.0**	**-0.5**	**-40.1**					
	% DIFFERENCE	0.0	0.0	-0.7	-57.3					
NON-HOV LANES	EXISTING HOV	40.4	40.4	40.4	40.4					
AVG SPEED	MODIFIED HOV	26.2	27.8	36.5	29.6					
MPH	DIFFERENCE	**-14.2**	**-12.6**	**-3.9**	**-10.8**					
	% DIFFERENCE	-35.1	-31.2	-9.7	-26.7					
TOTAL FUEL	EXISTING HOV	32131	32131	32131	32131					
CONSUMED	MODIFIED HOV	32835	33555	33301	34916	**DUE**	**DUE**	**DUE**	**DUE**	**DUE**
GALLONS	DIFFERENCE	**704**	**1424**	**1170**	**2785**					
	% DIFFERENCE	2.2	4.4	3.6	8.7					
EMFAC2002	EXISTING HOV	210	210	210	210					
HC EMISSIONS	MODIFIED HOV	250	248	224	257	**TO**	**TO**	**TO**	**TO**	**TO**
KILOGRAMS	DIFFERENCE	40	38	14	47					
	% DIFFERENCE	19.0	18.1	6.7	22.4					
EMFAC2002	EXISTING HOV	2369	2369	2369	2369					
CO EMISSIONS	MODIFIED HOV	2544	2586	2496	2697	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**
KILOGRAMS	DIFFERENCE	175	217	127	328					
	% DIFFERENCE	7.4	9.2	5.4	13.8					
EMFAC2002	EXISTING HOV	217	217	217	217					
NO EMISSIONS	MODIFIED HOV	225	229	225	237	**IN**	**IN**	**IN**	**IN**	**IN**
KILOGRAMS	DIFFERENCE	8	12	8	20					
	% DIFFERENCE	3.7	5.5	3.7	9.2					
EMFAC2002	EXISTING HOV	2796	2796	2796	2796					
TOTAL EMISSION	MODIFIED HOV	3019	3063	2945	3191	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**
KILOGRAMS	DIFFERENCE	**223**	**267**	**149**	**395**					
	% DIFFERENCE	8.0	9.5	5.3	14.1					

Figure 5.24 Effect of Demand Growth and 2+ Vehicle Percentages on Performance of Partial Barrier HOV Lane (GF=1.10)

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE FILE=I210WA-PB2-FINAL										
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
TOTAL	0.95	**-8.6**	**-16.5**	**-22.8**	**-25.8**					
TIME & DELAY	1.00	**23.4**	**11.4**	**0.0**	**-3.6**					
PASS-HRS	1.05	**39.2**	**33.1**	**25.9**	**30.4**					
(% Change)	1.10	**50.4**	**46.7**	**17.9**	**67.0**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE FILE=I210WA-PB2-FINAL										
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
FREEWAY	0.95	**-13.9**	**-9.0**	**-4.6**	**-0.2**					
TRAVEL	1.00	**2.9**	**5.1**	**0.0**	**6.0**					
PASS-MILES	1.05	**-11.9**	**-3.7**	**3.3**	**9.4**					
(% Change)	1.10	**-11.7**	**-3.3**	**4.0**	**11.2**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE FILE=I210WA-PB2-FINAL										
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
HOV VEHICLES	0.95	**0.0**	**0.0**	**0.0**	**-8.1**					
AVG SPEED	1.00	**0.0**	**0.0**	**0.0**	**-25.4**					
MPH	1.05	**0.0**	**0.0**	**-0.3**	**-43.7**					
(% Change)	1.10	**0.0**	**0.0**	**-0.7**	**-57.3**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE FILE=I210WA-PB2-FINAL										
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
NON-HOV	0.95	**0.0**	**11.9**	**26.7**	**41.1**					
VEHICLE	1.00	**-23.8**	**-12.6**	**0.0**	**14.1**					
AVG SPEED	1.05	**-31.2**	**-25.5**	**-18.8**	**-10.6**					
MPH (% Change)	1.10	**-35.1**	**-31.2**	**-9.7**	**-26.7**					

Figure 5.25A Summary Effect of Demand Growth Level and 2+ Vehicle Percentages on Performance of Partial Barrier HOV Lane

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE										FILE=I210WA-PB2-FINAL
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
TOTAL FUEL	0.95	**-5.3**	**-4.7**	**-4.2**	**-4.2**					
CONSUMED	1.00	**-1.0**	**-0.1**	**0.0**	**0.2**					
GALLONS	1.05	**0.8**	**2.7**	**4.2**	**5.0**					
(% Change)	1.10	**2.2**	**4.4**	**3.6**	**8.7**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE										FILE=I210WA-PB2-FINAL
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
EMFAC2002	0.95	**-5.0**	**-6.2**	**-7.0**	**-7.8**					
TOTAL EMISSION	1.00	**3.0**	**1.9**	**0.0**	**-1.2**					
KILOGRAMS	1.05	**5.8**	**7.0**	**7.1**	**7.3**					
(% Change)	1.10	**8.0**	**9.5**	**5.3**	**14.1**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE										FILE=I210WA-PB2-FINAL
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
FLOW LEVEL	0.95	**100-400**	**400-800**	**500-1200**	**700-1400**					
IN HOV LANE	1.00	**150-450**	**400-900**	**500-1300**	**700-1500**					
(VEHS/HOUR)	1.05	**200-450**	**400-950**	**500-1400**	**700-1500**					
	1.10	**200-500**	**400-1000**	**500-1450**	**700-1500**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE										FILE=I210WA-PB2-FINAL
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
LEVEL OF	0.95	**N/H**	**N/H**	**N/M**	**L/M**					
FREEWAY	1.00	**N/H**	**N/H**	**N/H**	**M/M**					
CONGESTION	1.05	**N/H**	**N/H**	**N/H**	**M/H**					
	1.10	**N/H**	**N/H**	**N/H**	**M/M**					

X/Y = LEVEL OF FREEWAY CONGESTION : HOV LANE/NON-HOV LANES   N= NONE   L=LIGHT   M=MODERATE   H=HEAVY

Figure 5.25B Summary Effect of Demand Growth Level and 2+ Vehicle Percentages on Performance of Partial Barrier HOV Lane

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE FILE=I210WA-PB2-FINAL

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
TOTAL FUEL	0.95	**30394**	**30606**	**30748**	**30746**					
CONSUMED	1.00	**31791**	**32078**	**32108**	**32180**					
(GALLONS)	1.05	**32376**	**32989**	**33458**	**33728**					
	1.10	**32835**	**33555**	**33301**	**34916**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE FILE=I210WA-PB2-FINAL

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
EMFAC2002	0.95	**2657**	**2624**	**2600**	**2577**					
TOTAL EMISSION	1.00	**2881**	**2849**	**2796**	**2763**					
(KILOGRAMS)	1.05	**2958**	**2991**	**2994**	**2999**					
	1.10	**3019**	**3063**	**2945**	**3191**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE FILE=I210WA-PB2-FINAL

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
TOTAL TIME AND	0.95	**13918**	**12716**	**11758**	**11299**					
DELAY	1.00	**18794**	**16959**	**15229**	**14674**					
(PASS-HRS)	1.05	**21199**	**20277**	**19172**	**19864**					
	1.10	**22911**	**22342**	**17954**	**25434**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE FILE=I210WA-PB2-FINAL

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
TOTAL TRAVEL	0.95	**570974**	**603060**	**632511**	**661633**					
DISTANCE	1.00	**587154**	**629110**	**662795**	**694547**					
(PASS-MILES)	1.05	**584171**	**638474**	**684981**	**725324**					
	1.10	**585539**	**640751**	**689346**	**736759**					

Figure 5.25C Summary Effect of Demand Growth Level and 2+ Vehicle Percentages on Performance of Partial Barrier HOV Lane

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE FILE=I210WA-PB2-FINAL										
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
AVERAGE	0.95	**18.8**	**19.7**	**20.6**	**21.5**					
FUEL	1.00	**18.5**	**19.6**	**20.6**	**21.6**					
CONSUMPTION	1.05	**18.0**	**19.4**	**20.5**	**21.5**					
(Pass-Miles/Gal)	1.10	**17.8**	**19.1**	**20.7**	**21.1**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE FILE=I210WA-PB2-FINAL										
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
AVERAGE	0.95	**214.9**	**229.8**	**243.3**	**256.7**					
VEHICLE	1.00	**203.8**	**220.8**	**237.1**	**251.4**					
EMISSIONS	1.05	**197.5**	**213.5**	**228.8**	**241.9**					
(Pass-Miles/Kilo)	1.10	**194.0**	**209.2**	**234.1**	**230.9**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE FILE=I210WA-PB2-FINAL										
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
AVERAGE	0.95	**41.0**	**47.4**	**53.8**	**58.6**					
VEHICLE	1.00	**31.2**	**37.1**	**43.5**	**47.3**					
SPEEDS	1.05	**27.6**	**31.5**	**35.7**	**36.5**					
(mph)	1.10	**25.6**	**28.7**	**38.4**	**29.0**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF EXISTING PARTIAL BARRIER HOV LANE FILE=I210WA-PB2-FINAL										
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
HOV SPEED	0.95	**29.6**	**24.8**	**18.8**	**7.3**					
MINUS	1.00	**39.2**	**34.7**	**29.6**	**6.1**					
NON-HOV SPEED	1.05	**42.2**	**39.9**	**37.0**	**3.3**					
(mph)	1.10	**43.8**	**42.2**	**33.0**	**0.3**					

Figure 5.25D Summary Effect of Demand Growth Level and 2+ Vehicle Percentages on Performance of Partial Barrier HOV Lane

5.3.6 INVESTIGATION OF MODIFIED HOV LANE FOR 2+ VEHICLES WITH INCREASED HOV INTERMITTENT BARRIERS

The analysis reported in the previous section with the existing HOV design indicated that the HOV lane would become congested at relatively low percentages of 2+ HOV vehicles. It also indicated that the quality of travel in the HOV lane began to not be superior to the quality of travel in the non-HOV lanes.

This suggested that either the demand in the HOV lane needed to be reduced or the capacity of the HOV portion of the freeway needed to be increased. This led to a review of the existing HOV design and operational features previously listed and an assessment of possible ways to maintain a high quality of travel for the HOV vehicles and a better quality than for non-HOV vehicles.

In terms of increasing the capacity of the HOV portion of the freeway, the most obvious alternative would be to designate a second lane for HOV vehicles. Either an added new lane could be considered or converting an existing non-HOV lane. Neither alternative seemed particularly attractive because of the costs or severe congestion that would occur in the non-HOV lanes. They were not investigated in this further analysis.

Another alternative would be to change the HOV cut-off limit from 2+ vehicles to 3+ vehicles. This is contrary to current policy in this district and it is questionable that it would be effective with such a low percentage of 3+ vehicles. If district policy permitted, another possibility would be to change the cut-off limit from 2+ vehicles to 3+ vehicles but add some additional vehicles with special requirements such as tolls, more-energy efficient vehicles, etc. However they were not investigated in this further analysis.

The length of the HOV lane could be shortened and thus reduce the excess demand for the HOV lane. Since the full length HOV lane is currently in operation it did not seem feasible to consider reducing its length.

While district policy suggests operating the HOV lane on a 24-hour seven-day week basis, only the peak period was considered in the previous analysis because data was not available. While extending the analysis beyond the peak period would be desirable, it would not alleviate the operational results obtained in the previous analysis.

The existing HOV design included an intermittent HOV barrier with six intermittent access points between the HOV lane and the non-HOV lanes. By reducing the number of access points, the HOV lane usage would be reduced. This reduction would result in a higher quality of flow for the HOV vehicles, a quality of flow in the HOV lane superior to the quality of flow in the non-HOV lanes, and could handle higher 2+ percentages of HOV vehicles. This alternative is investigated in this section and the intermittent access points were reduced from six to two. The two intermittent access points were selected to permit traffic entering the I-210 freeway from the I-605 to the use the HOV lane and also for HOV vehicles to leave the freeway to exit on the right-side exit connector to the I-210 north.

Sensitivity analysis was continued in regard to the vehicle occupancy distribution and the freeway demand level but based upon the new reduced intermittent barrier design discussed earlier.

5.3.6.1 Sensitivity Analysis of Vehicle Occupancy Distribution and Anticipated Future Growth

As mentioned earlier, the vehicle occupancy distribution and anticipated future growth have a significant impact on the success of an added HOV lane operation. Thus a sensitivity analysis was undertaken in which the percent of vehicles carrying 2+ persons will vary from 4% to 36% in 4% intervals (with 12% 2+ vehicles representing base conditions). The freeway demand level was also varied from 0.95 to 1.10 (in steps of 0.05) with an initial value of 1.00 representing the year 2004 freeway demand level.

The results of these sensitivity analysis investigations are summarized in Figures 5.26, 5.27, 5.28, and 5.29 with each figure representing a different freeway demand level (0.95, 1.00, 1.05, and 1.10). The rows in each figure represent measures of performances while the vertical columns represent the percent vehicles carry 2+ vehicles ranging from 4% to 36%. The results for each of the four freeway demand levels are discussed in the following four sections. The calculation of differences and percent differences in measures of performance are based upon the two intermittent barrier design; the existing and the modified (openings reduced from six to two).

5.3.6.2 Impact of 2+ HOV Lane with 0.95 Freeway Demand Level

Figure 5.26 presents the impacts of a 2+ HOV lane with a freeway demand level of 0.95 and with a varying percent of vehicles carrying 2+ persons from 4% to 36%. Special attention will be given to six performance measures that are shown in bold type. There were three levels of HOV lane operations encountered depending upon the 2+% HOV percentage.

The first level of HOV operations occurred when the 2+ HOV percentage was 16% or less. Both barrier design alternatives could be analyzed with little or no congestion in the HOV lane and with travel in the HOV lane superior to travel in the non-HOV lanes. The downsides of the reduced number of openings were increased total travel time and delay, reduced total passenger-miles served, increased fuel consumed, and increased vehicle emissions. The primary benefit was that congestion did not occur in the HOV lane and the quality of travel in the HOV lane was superior to the quality of travel in the non-HOV lane when the 2+ HOV percentage was 16%. These differences were due to fewer vehicles using the HOV lane and greater traffic demands in the non-HOV lanes. Shorter length HOV vehicle trips were forced to remain in the non-HOV lanes.

The second level of HOV operations occurred when the 2+ HOV percentage was 20 to 24%. With the existing intermittent HOV barrier design, the HOV lane became congested and queues extended back into the non-HOV lanes. With the reduced HOV lane openings, the HOV lane was not congested and the quality of travel in the HOV lane was superior to the quality of travel when the 2+ percentage was 20%.

The third level of HOV operations occurred when the 2+ HOV percentage was 28% or greater. Results for both the existing and reduced number of HOV lane openings indicated congestion in the HOV lane and queues extended back into the HOV lane.

5.3.6.3 Impact of 2+ HOV Lane with 1.00 Freeway Demand Level

Figure 5.27 presents the impacts of a 2+ HOV lane with a freeway demand level of 1.00 and with a varying percent of vehicles carrying 2+ persons from 4% to 36%. Special attention will be given to six performance measures that are shown in bold type. There were three levels of HOV lane operations encountered depending upon the 2+% HOV percentage.

The first level of HOV operations occurred when the 2+ HOV percentage was 16% or less. Both barrier design alternatives could be analyzed with little or no congestion in the HOV lane and with travel in the HOV lane superior to travel in the non-HOV lanes. The downsides of the reduced number of openings were increased total travel time and delay (except for 4% 2+ HOV vehicles), reduced total passenger-miles served, increased fuel consumed, and increased vehicle emissions. The primary benefit was that congestion did not occur in the HOV lane and the quality of travel in the HOV lane was superior to the quality of travel in the non-HOV lane when the 2+ HOV percentage was 16%. These differences was due to fewer vehicles using the HOV lane and greater traffic demands in the non-HOV lanes. Shorter length HOV vehicle trips were forced to remain in the non-HOV lanes.

The second level of HOV operations occurred when the 2+ HOV percentage was 20 to 24%. With the existing intermittent HOV barrier design, the HOV lane became congested and queues extended back into the non-HOV lanes. With the reduced HOV lane openings, the HOV lane was not congested and the quality of travel in the HOV lane was superior to the quality of travel when the 2+ percentage was 20%.

The third level of HOV operations occurred when the 2+ HOV percentage was 28% or greater. Results for both the existing and reduced number of HOV lane openings indicated congestion in the HOV lane and queues extended back into the HOV lane.

5.3.6.4 Impact of 2+ HOV Lane with 1.05 Freeway Demand Level

Figure 5.28 presents the impacts of a 2+ HOV lane with a freeway demand level of 1.05 and with a varying percent of vehicles carrying 2+ persons from 4% to 36%. Special attention will be given to six performance measures that are shown in bold type. There were three levels of HOV lane operations encountered depending upon the 2+% HOV percentage.

The first level of HOV operations occurred when the 2+ HOV percentage was 16% or less. Both barrier design alternatives could be analyzed with little or no congestion in the HOV lane and with travel in the HOV lane superior to travel in the non-HOV lanes. The downsides of the reduced number of openings were increased total travel time and delay (except for 4% 2+ HOV vehicles), reduced total passenger-miles served, increased fuel consumed, and increased vehicle emissions. The primary benefit was that congestion did not occur in the HOV lane and the quality of travel in the HOV lane was superior to the quality of travel in the non-HOV lane when the 2+ HOV percentage was 16%. These differences was due to fewer vehicles using the HOV lane and greater traffic demands in the non-HOV lanes. Shorter length HOV vehicle trips were forced to remain in the non-HOV lanes.

The second level of HOV operations occurred when the 2+ HOV percentage was 20%. With the existing intermittent HOV barrier design, the HOV lane became congested and queues extended back into the non-HOV lanes. With the reduced number of HOV lane openings, the HOV lane was not congested and the quality of travel in the HOV lane was superior to the quality of travel when the 2+ percentage was 20%.

The third level of HOV operations occurred when the 2+ HOV percentage was 24% or greater. Results for both the existing and reduced number of HOV lane openings indicated congestion in the HOV lane and queues extended back into the HOV lane.

5.3.6.5 Impact of 2+ HOV Lane with 1.10 Freeway Demand Level

Figure 5.29 presents the impacts of a 2+ HOV lane with a freeway demand level of 1.10 and with a varying percent of vehicles carrying 2+ persons from 4% to 36%. Special attention will be given to six performance measures that are shown in bold type. There were three levels of HOV lane operations encountered depending upon the 2+% HOV percentage.

The first level of HOV operations occurred when the 2+ HOV percentage was 16% or less. Both barrier design alternatives could be analyzed with little or no congestion in the HOV lane and with travel in the HOV lane superior to travel in the non-HOV lanes. The downsides of the reduced number of openings were increased total travel time and delay (except for 4% 2+ HOV vehicles), reduced total passenger-miles served, increased fuel consumed, and increased vehicle emissions. The primary benefit was that congestion did not occur in the HOV lane and the quality of travel in the HOV lane was superior to the quality of travel in the non-HOV lane when the 2+ HOV percentage was 16%. These differences were due to fewer vehicles using the HOV lane and greater traffic demands in the non-HOV lanes. Shorter length HOV vehicle trips were forced to remain in the non-HOV lanes.

The second level of HOV operations occurred when the 2+ HOV percentage was 20%. With the existing intermittent HOV barrier design, the HOV lane became congested and queues extended back into the non-HOV lanes. With the reduced number of HOV lane openings, the HOV lane was not congested and the quality of travel in the HOV lane was superior to the quality of travel when the 2+ percentage was 20%.

The third level of HOV operations occurred when the 2+ HOV percentage was 24% or greater. Results for both the existing and reduced number of HOV lane openings indicated congestion in the HOV lane and queues extended back into the HOV lane.

5.3.6.6 Overall Summary of Results on Each Measure of Performance

Sensitivity of results presented on a percentage basis for sixteen selected measures of performance is shown in Figures 5.30A, 5.30B, 5.30C, and 5.30D. The percent changes are based upon the performance differences between the existing intermittent barrier design and the reduced number of HOV lane access barrier openings design. Both the effects of 2+ HOV vehicle percentages and growth factors can be observed in each of the tables of these four figures. Since the HOV lane with the existing barrier design became congested and queues extended back into the non-HOV lanes when the 2+ HOV percentage reached 20%, the only percent changes that can be shown are for 2+ HOV vehicle percentages ranging from 4 to 16%.

Comments on each of the sixteen selected measures of performance are presented in the following sixteen paragraphs.

The percent change in total time and delay in passenger-hours are almost always positive in that reducing the number of openings to the HOV lane resulted in greater total time and delay. This was particularly true at higher 2+ percentages of HOV vehicles (Figure 5.30A).

The percent changes in freeway travel in passenger-miles are almost always negative in that reducing the number of openings to the HOV lane resulted in fewer passenger-miles served. The highest percent changes occurred at the higher growth factors combined with the higher 2+ HOV vehicle percentages (Figure 5.30A).

The percent change in overall average HOV vehicle speeds in mph are unchanged under lower traffic demand levels combined with lower percentage of 2+ % HOV vehicles. There were significant increases in HOV lane speeds with a 16% 2+ HOV vehicle percentage (Figure 5.30A).

The percent changes in overall average non-HOV vehicle speeds in mph are all negative. This indicated that reducing the number of access points to the HOV lane resulted in greater demands in the non-HOV lanes and reduced speeds. This was particularly true at higher 2+ HOV vehicle percentages (Figure 5.30A).

The percent change in total fuel consumed increased when the number of access points to the HOV lane decreased. The increase varied from 2% to 5% (Figure 5.30B).

The percentage change in total emissions pretty much followed the pattern of percent changes in total fuel consumed. That is, total emissions increased in almost every case. The increase varied from 1% to 8% (Figure 5.30B).

Another set of results that is often helpful is the level of flow in the HOV lane. Low flows in the HOV lane indicate that the added HOV lane is not being effectively used and also non-HOV users particularly may be concerned about this under-utilization. Obviously high flows approaching the capacity of the HOV lane are of concern because of the poor level of service being provided to HOV users and also because of not having available capacity for future HOV growth. With a 4% 2+ HOV vehicle percentage, the HOV operated at less than 20% full while at a 20% or more 2+ HOV vehicle percentage, the HOV lane was operating at capacity or was slightly congested. The results in this table clearly demonstrates why the percentage of HOV vehicles and a level of accuracy of this percentage is crucial in evaluating freeway HOV lanes (Figure 5.30B)..

Another set of results that is often informative is the level of freeway congestion in the HOV lane and the non-HOV lanes. For each cell in the final table of Figure 5.30B, there is a code of two letters indicating the level of freeway congestion in the HOV lane and in the non-HOV lanes. The following letters are used to indicate the level of congestion: no congestion (N), light congestion (L), moderate congestion (M), and heavy congestion (H). The designation of light, moderate, and heavy congestion is determined qualitatively for comparison purposes. For the HOV lane, there is no congestion in this lane until the 2+ % HOV vehicle level approaches 24% and the level of congestion changes from little to moderate as the growth factor increases. For the non-HOV lanes, there is always heavy congestion in these lanes except under lower growth factors combined with higher 2+ % HOV vehicles when the congestion level is classified as being moderate (Figure 5.30B).

The four tables contained in Figure 5.30C provide total quantities expended in fuel consumption, vehicle emissions, passenger-time, and passenger-hours. These total quantities can be misleading in assessing the implementation of HOV lanes. For example, the total passenger-miles traveled within the study section and study duration period varied between investigations. Hence total fuel consumption, vehicle emissions, and passenger-hours would be expected to vary due to different levels of total passenger-miles of travel as well as due to the appropriateness of the HOV lane design.

The total quantities shown in Figure 5.30C were used to create the first three tables contained in Figure 5.30D.

Average fuel consumption rates (passenger-miles per gallon) are displayed in the first table of Figure 5.30D. The average fuel consumption rates varied from 16.9 to 22.6 passenger-miles per gallon. The highest rates occurred at higher percentage of 2+ HOV vehicles combined with lower growth rates. The lowest rates occurred at lower percentage of 2+ HOV vehicles combined with higher growth factors (Figure 5.30D).

Average vehicle emission rates (passenger-miles per kilogram) are displayed in the second table of Figure 5.30D. The results for average vehicle emission rates were similar to those for average fuel consumption rates. The highest rates occurred at higher percentage of 2+ HOV vehicles combined with lower growth rates. The lowest rates occurred at lower percentage of 2+ HOV vehicles combined with higher growth factors.

Average vehicle speeds (miles per hour) are displayed in the third table of Figure 5.30D. Another way of looking at this rate is in terms of passenger-miles traveled per hour of time. The average vehicle speeds varied from 24.6 to 53.9. Higher average vehicle speeds occurred at lower growth factors and higher 2+ HOV vehicle percentages. The contrary was true for lower average vehicle speeds. Growth factor affected the results more than the percentage of 2+ HOV vehicles.

The final table in Figure 5.30D displays the differential average speeds (mph) between the HOV lane and the non-HOV lanes for various traffic demand levels and percentages of 2+ HOV vehicles. This differential average speed is one of the primary incentives for encouraging the HOV vehicles to use the HOV lane and for creating new HOV vehicles. Differential average speeds of 20 to 44 mph occurred when the percentage of 2+ HOV vehicles was 20% or less. There was little incentive for encouraging carpooling at a 2+ HOV vehicle percentage level of 24%.

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE (GF=0.95)									FILE=I210WA-RPB2-FINAL	
MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 0.95 2+ HOV = 4%	GF = 0.95 2+ HOV = 8%	GF = 0.95 2+ HOV = 12%	GF = 0.95 2+ HOV = 16%	GF = 0.95 2+ HOV = 20%	GF = 0.95 2+ HOV = 24%	GF = 0.95 2+ HOV = 28%	GF = 0.95 2+ HOV = 32%	GF = 0.95 2+ HOV = 36%
FREEWAY	EXIST BARRIER	13743	12672	11758	11299	NA	NA			
TRAVEL TIME	MOD. BARRIER	14593	14479	14100	13440	13131	13322	**QUEUE**	**QUEUE**	**QUEUE**
PASS-HRS	DIFFERENCE	850	1807	2342	2141					
	% DIFFERENCE	6.2	14.3	19.9	18.9					
RAMP	EXIST BARRIER	175	44	0	0	NA	NA			
DELAY	MOD. BARRIER	202	115	0	0	0	0	**OUT**	**OUT**	**OUT**
PASS-HRS	DIFFERENCE	27	71	0	0					
	% DIFFERENCE	15.4	161.4	0.0	0.0					
TOTAL	EXIST BARRIER	13918	12716	11758	11299	NA	NA			
TIME & DELAY	MOD. BARRIER	14795	14594	14100	13440	13131	13322	**OF**	**OF**	**OF**
PASS-HRS	DIFFERENCE	**877**	**1878**	**2342**	**2141**					
	% DIFFERENCE	6.3	14.8	19.9	18.9					
FREEWAY	EXIST BARRIER	570974	603060	632511	661633	NA	NA			
TRAVEL	MOD. BARRIER	570330	602210	632835	660468	689340	718388	**HOV**	**HOV**	**HOV**
PASS-MILES	DIFFERENCE	**-644**	**-850**	**324**	**-1165**					
	% DIFFERENCE	-0.1	-0.1	0.1	-0.2					
HOV LANE	EXIST BARRIER	70.0	70.0	70.0	64.3	NA	NA			
AVG SPEED	MOD. BARRIER	70.0	70.0	70.0	70.0	69.9	56.5	**LANE**	**LANE**	**LANE**
MPH	DIFFERENCE	**0.0**	**0.0**	**0.0**	**5.7**					
	% DIFFERENCE	0.0	0.0	0.0	8.9					
NON-HOV LANES	EXIST BARRIER	40.4	45.2	51.2	57.0	NA	NA			
AVG SPEED	MOD. BARRIER	38.2	40.2	42.9	46.8	49.9	53.4			
MPH	DIFFERENCE	**-2.2**	**-5.0**	**-8.3**	**-10.2**					
	% DIFFERENCE	-5.4	-11.1	-16.2	-17.9					
TOTAL FUEL	EXIST BARRIER	30394	30606	30748	30746	NA	NA			
CONSUMED	MOD. BARRIER	31902	32011	32024	32004	31911	31822	**DUE**	**DUE**	**DUE**
GALLONS	DIFFERENCE	**1508**	**1405**	**1276**	**1258**					
	% DIFFERENCE	5.0	4.6	4.1	4.1					
EMFAC2002	EXIST BARRIER	199	194	191	187	NA	NA			
HC EMISSIONS	MOD. BARRIER	213	210	206	202	199	196	**TO**	**TO**	**TO**
KILOGRAMS	DIFFERENCE	14	16	15	15					
	% DIFFERENCE	7.0	8.2	7.9	8.0					
EMFAC2002	EXIST BARRIER	2251	2224	2203	2186	NA	NA			
CO EMISSIONS	MOD. BARRIER	2344	2336	2317	2291	2274	2259	**CONGESTION**	**CONGESTION**	**CONGESTION**
KILOGRAMS	DIFFERENCE	93	112	114	105					
	% DIFFERENCE	4.1	5.0	5.2	4.8					
EMFAC2002	EXIST BARRIER	207	206	206	204	NA	NA			
NO EMISSIONS	MOD. BARRIER	212	212	212	210	209	208	**IN**	**IN**	**IN**
KILOGRAMS	DIFFERENCE	5	6	6	6					
	% DIFFERENCE	2.4	2.9	2.9	2.9					
EMFAC2002	EXIST BARRIER	2657	2624	2600	2577	NA	NA			
TOTAL EMISSION	MOD. BARRIER	2769	2758	2735	2703	2682	2663	**HOV LANE**	**HOV LANE**	**HOV LANE**
KILOGRAMS	DIFFERENCE	**112**	**134**	**135**	**126**					
	% DIFFERENCE	4.2	5.1	5.2	4.9					

Figure 5.26 Effect of Demand Growth and 2+ Vehicle Percentages on Performance of Partial Barrier and Reduced Partial Barrier HOV Lane (GF=0.95)

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE (GF=1.00)										FILE=I210WA-RPB2-FINAL
MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 1.00 2+ HOV = 4%	GF = 1.00 2+ HOV = 8%	GF = 1.00 2+ HOV = 12%	GF = 1.00 2+ HOV = 16%	GF = 1.00 2+ HOV = 20%	GF = 1.00 2+ HOV = 24%	GF = 1.00 2+ HOV = 28%	GF = 1.00 2+ HOV = 32%	GF = 1.00 2+ HOV = 36%
FREEWAY	EXIST BARRIER	18356	16708	15139	14640	NA	NA			
TRAVEL TIME	MOD. BARRIER	17779	17695	18943	18934	17986	18677	**QUEUE**	**QUEUE**	**QUEUE**
PASS-HRS	DIFFERENCE	-577	987	3804	4294					
	% DIFFERENCE	-3.1	5.9	25.1	29.3					
RAMP	EXIST BARRIER	438	251	90	34	NA	NA			
DELAY	MOD. BARRIER	423	324	215	93	36	37	**OUT**	**OUT**	**OUT**
PASS-HRS	DIFFERENCE	-15	73	125	59					
	% DIFFERENCE	-3.4	29.1	138.9	173.5					
TOTAL	EXIST BARRIER	18794	16959	15229	14674	NA	NA			
TIME & DELAY	MOD. BARRIER	18202	18019	19158	19027	18022	18714	**OF**	**OF**	**OF**
PASS-HRS	DIFFERENCE	**-592**	**1060**	**3929**	**4353**					
	% DIFFERENCE	-3.1	6.3	25.8	29.7					
FREEWAY	EXIST BARRIER	587154	629110	662795	694547	NA	NA			
TRAVEL	MOD. BARRIER	581384	619130	655840	693003	727154	756528	**HOV**	**HOV**	**HOV**
PASS-MILES	DIFFERENCE	**-5770**	**-9980**	**-6955**	**-1544**					
	% DIFFERENCE	-1.0	-1.6	-1.0	-0.2					
HOV LANE	EXIST BARRIER	70.0	70.0	70.0	52.2	NA	NA			
AVG SPEED	MOD. BARRIER	70.0	70.0	70.0	70.0	69.8	41.1	**LANE**	**LANE**	**LANE**
MPH	MIXED-FLOW	**0.0**	**0.0**	**0.0**	**17.8**					
	HOV DIFF	0.0	0.0	0.0	34.1					
NON-HOV LANES	EXIST BARRIER	31.9	35.3	40.4	46.1	NA	NA			
AVG SPEED	MOD. BARRIER	30.8	33.4	32.3	33.7	**37.0**	**40.3**			
MPH	% DIFF HOV	**-1.1**	**-1.9**	**-8.1**	**-12.4**					
	%DIFF NON-HOV	-3.4	-5.4	-20.0	-26.9					
TOTAL FUEL	EXIST BARRIER	31791	32078	32108	32180	NA	NA			
CONSUMED	MOD. BARRIER	32812	33248	33626	33851	33900	33724	**DUE**	**DUE**	**DUE**
GALLONS	DIFFERENCE	**1021**	**1170**	**1518**	**1671**					
	% DIFFERENCE	3.2	3.6	4.7	5.2					
EMFAC2002	EXIST BARRIER	227	219	210	205	NA	NA			
HC EMISSIONS	MOD. BARRIER	232	231	235	233	227	223	**TO**	**TO**	**TO**
KILOGRAMS	DIFFERENCE	5	12	25	28					
	% DIFFERENCE	2.2	5.5	11.9	13.7					
EMFAC2002	EXIST BARRIER	2436	2412	2369	2342	NA	NA			
CO EMISSIONS	MOD. BARRIER	2467	2479	2510	2513	2489	2464	**CONGESTION**	**CONGESTION**	**CONGESTION**
KILOGRAMS	DIFFERENCE	31	67	141	171					
	% DIFFERENCE	1.3	2.8	6.0	7.3					
EMFAC2002	EXIST BARRIER	218	218	217	216	NA	NA			
NO EMISSIONS	MOD. BARRIER	220	222	224	225	224	222	**IN**	**IN**	**IN**
KILOGRAMS	DIFFERENCE	2	4	7	9					
	% DIFFERENCE	0.9	1.8	3.2	4.2					
EMFAC2002	EXIST BARRIER	2881	2849	2796	2763	NA	NA			
TOTAL EMISSION	MOD. BARRIER	2919	2932	2969	2971	2940	2909	**HOV LANE**	**HOV LANE**	**HOV LANE**
KILOGRAMS	DIFFERENCE	**38**	**83**	**173**	**208**					
	% DIFFERENCE	1.3	2.9	6.2	7.5					

Figure 5.27 Effect of Demand Growth and 2+ Vehicle Percentages on Performance of Partial Barrier and Reduced Partial Barrier HOV Lane (GF=1.00)

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE (GF=1.05)										FILE=I210WA-RPB2-FINAL
MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 1.05 2+ HOV = 4%	GF = 1.05 2+ HOV = 8%	GF = 1.05 2+ HOV = 12%	GF = 1.05 2+ HOV = 16%	GF = 1.05 2+ HOV = 20%	GF = 1.05 2+ HOV = 24%	GF = 1.05 2+ HOV = 28%	GF = 1.05 2+ HOV = 32%	GF = 1.05 2+ HOV = 36%
FREEWAY	EXIST BARRIER	20132	19637	18814	19642	NA				
TRAVEL TIME	MOD. BARRIER	20378	20998	21665	22365	22961	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**
PASS-HRS	DIFFERENCE	246	1361	2851	2723					
	% DIFFERENCE	1.2	6.9	15.2	13.9					
RAMP	EXIST BARRIER	1067	640	358	222	NA				
DELAY	MOD. BARRIER	1124	975	861	719	478	**OUT**	**OUT**	**OUT**	**OUT**
PASS-HRS	DIFFERENCE	57	335	503	497					
	% DIFFERENCE	5.3	52.3	140.5	223.9					
TOTAL	EXIST BARRIER	21199	20277	19172	19864	NA				
TIME & DELAY	MOD. BARRIER	21502	21973	22526	23084	23439	**OF**	**OF**	**OF**	**OF**
PASS-HRS	DIFFERENCE	**303**	**1696**	**3354**	**3220**					
	% DIFFERENCE	1.4	8.4	17.5	16.2					
FREEWAY	EXIST BARRIER	584171	638474	684981	725324	NA				
TRAVEL	MOD. BARRIER	576059	616537	656952	697689	738261	**HOV**	**HOV**	**HOV**	**HOV**
PASS-MILES	DIFFERENCE	**-8112**	**-21937**	**-28029**	**-27635**					
	% DIFFERENCE	-1.4	-3.4	-4.1	-3.8					
HOV LANE	EXIST BARRIER	70.0	70.0	69.8	39.4	NA				
AVG SPEED	MOD. BARRIER	70.0	70.0	70.0	70.0	69.4	**LANE**	**LANE**	**LANE**	**LANE**
MPH	DIFFERENCE	**0.0**	**0.0**	**0.2**	**30.6**					
	% DIFFERENCE	0.0	0.0	0.3	77.7					
NON-HOV LANES	EXIST BARRIER	27.8	30.1	32.8	36.1	NA				
AVG SPEED	MOD. BARRIER	27.4	27.7	28.0	28.2	28.5				
MPH	DIFFERENCE	**-0.4**	**-2.4**	**-4.8**	**-7.9**					
	% DIFFERENCE	-1.4	-8.0	-14.6	-21.9					
TOTAL FUEL	EXIST BARRIER	32376	32989	33458	33728	NA				
CONSUMED	MOD. BARRIER	33456	33903	34374	34855	35265	**DUE**	**DUE**	**DUE**	**DUE**
GALLONS	DIFFERENCE	**1080**	**914**	**916**	**1127**					
	% DIFFERENCE	3.3	2.8	2.7	3.3					
EMFAC2002	EXIST BARRIER	241	237	233	231	NA				
HC EMISSIONS	MOD. BARRIER	249	251	252	254	255	**TO**	**TO**	**TO**	**TO**
KILOGRAMS	DIFFERENCE	8	14	19	23					
	% DIFFERENCE	3.3	5.9	8.2	10.0					
EMFAC2002	EXIST BARRIER	2496	2529	2534	2540	NA				
CO EMISSIONS	MOD. BARRIER	2542	2569	2597	2626	2648	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**
KILOGRAMS	DIFFERENCE	46	40	63	86					
	% DIFFERENCE	1.8	1.6	2.5	3.4					
EMFAC2002	EXIST BARRIER	221	225	227	228	NA				
NO EMISSIONS	MOD. BARRIER	224	227	229	232	234	**IN**	**IN**	**IN**	**IN**
KILOGRAMS	DIFFERENCE	3	2	2	4					
	% DIFFERENCE	1.4	0.9	0.9	1.8					
EMFAC2002	EXIST BARRIER	2958	2991	2994	2999	NA				
TOTAL EMISSION	MOD. BARRIER	3015	3047	3078	3112	3137	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**
KILOGRAMS	DIFFERENCE	**57**	**56**	**84**	**113**					
	% DIFFERENCE	1.9	1.9	2.8	3.8					

Figure 5.28 Effect of Demand Growth and 2+ Vehicle Percentages on Performance of Partial Barrier and Reduced Partial Barrier HOV Lane (GF=1.05)

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE (GF=1.10) FILE=I210WA-RPB2-FINAL

MEASURES OF PERFORMANCE	PERFORMANCE OF	GF = 1.10 2+ HOV = 4%	GF = 1.10 2+ HOV = 8%	GF = 1.10 2+ HOV = 12%	GF = 1.10 2+ HOV = 16%	GF = 1.10 2+ HOV = 20%	GF = 1.10 2+ HOV = 24%	GF = 1.10 2+ HOV = 28%	GF = 1.10 2+ HOV = 32%	GF = 1.10 2+ HOV = 36%
FREEWAY	EXIST BARRIER	21277	21143	17177	24695	NA				
TRAVEL TIME	MOD. BARRIER	21587	22380	23158	23958	24701	**QUEUE**	**QUEUE**	**QUEUE**	**QUEUE**
PASS-HRS	DIFFERENCE	310	1237	5981	-737					
	% DIFFERENCE	1.5	5.9	34.8	-3.0					
RAMP	EXIST BARRIER	1634	1199	777	739	NA				
DELAY	MOD. BARRIER	1761	1665	1537	1429	1084	**OUT**	**OUT**	**OUT**	**OUT**
PASS-HRS	DIFFERENCE	127	466	760	690					
	% DIFFERENCE	7.8	38.9	97.8	93.4					
TOTAL	EXIST BARRIER	22911	22342	17954	25434	NA				
TIME & DELAY	MOD. BARRIER	23348	24045	24695	25387	25785	**OF**	**OF**	**OF**	**OF**
PASS-HRS	DIFFERENCE	**437**	**1703**	**6741**	**-47**					
	% DIFFERENCE	1.9	7.6	37.5	-0.2					
FREEWAY	EXIST BARRIER	585539	640751	689346	736759	NA				
TRAVEL	MOD. BARRIER	574112	616260	658138	700066	742164	**HOV**	**HOV**	**HOV**	**HOV**
PASS-MILES	DIFFERENCE	**-11427**	**-24491**	**-31208**	**-36693**					
	% DIFFERENCE	-2.0	-3.8	-4.5	-5.0					
HOV LANE	EXIST BARRIER	70.0	70.0	69.5	29.9	NA				
AVG SPEED	MOD. BARRIER	70.0	70.0	70.0	70.0	66.1	**LANE**	**LANE**	**LANE**	**LANE**
MPH	MIXED-FLOW	**0.0**	**0.0**	**0.5**	**40.1**					
	HOV DIFF	0.0	0.0	0.7	134.1					
NON-HOV LANES	EXIST BARRIER	26.2	27.8	36.5	29.6	NA				
AVG SPEED	MOD. BARRIER	25.7	25.9	26.0	26.1	**26.4**				
MPH	% DIFF HOV	**-0.5**	**-1.9**	**-10.5**	**-3.5**					
	%DIFF NON-HOV	-1.9	-6.8	-28.8	-11.8					
TOTAL FUEL	EXIST BARRIER	32835	33555	33301	34916	NA				
CONSUMED	MOD. BARRIER	33961	34489	34979	35505	35929	**DUE**	**DUE**	**DUE**	**DUE**
GALLONS	DIFFERENCE	**1126**	**934**	**1678**	**589**					
	% DIFFERENCE	3.4	2.8	5.0	1.7					
EMFAC2002	EXIST BARRIER	250	248	224	257	NA				
HC EMISSIONS	MOD. BARRIER	259	262	263	266	266	**TO**	**TO**	**TO**	**TO**
KILOGRAMS	DIFFERENCE	9	14	39	9					
	% DIFFERENCE	3.6	5.6	17.4	3.5					
EMFAC2002	EXIST BARRIER	2544	2586	2496	2697	NA				
CO EMISSIONS	MOD. BARRIER	2588	2622	2653	2686	2707	**CONGESTION**	**CONGESTION**	**CONGESTION**	**CONGESTION**
KILOGRAMS	DIFFERENCE	44	36	157	-11					
	% DIFFERENCE	1.7	1.4	6.3	-0.4					
EMFAC2002	EXIST BARRIER	225	229	225	237	NA				
NO EMISSIONS	MOD. BARRIER	227	230	233	236	238	**IN**	**IN**	**IN**	**IN**
KILOGRAMS	DIFFERENCE	2	1	8	-1					
	% DIFFERENCE	0.9	0.4	3.6	-0.4					
EMFAC2002	EXIST BARRIER	3019	3063	2945	3191	NA				
TOTAL EMISSION	MOD. BARRIER	3074	3114	3149	3188	3211	**HOV LANE**	**HOV LANE**	**HOV LANE**	**HOV LANE**
KILOGRAMS	DIFFERENCE	**55**	**51**	**204**	**-3**					
	% DIFFERENCE	1.8	1.7	6.9	-0.1					

Figure 5.29 Effect of Demand Growth and 2+ Vehicle Percentages on Performance of Partial Barrier and Reduced Partial Barrier HOV Lane (GF=1.10)

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE FILE=I210WA-RPB2-FINAL

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
TOTAL	0.95	**6.3**	**14.8**	**19.9**	**18.9**					
TIME & DELAY	1.00	**-3.1**	**6.3**	**25.8**	**29.7**					
PASS-HRS	1.05	**1.4**	**8.4**	**17.5**	**16.2**					
(% Change)	1.10	**1.9**	**7.6**	**37.5**	**-0.2**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE FILE=I210WA-RPB2-FINAL

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
FREEWAY	0.95	**-0.1**	**-0.1**	**0.1**	**-0.2**					
TRAVEL	1.00	**-1.0**	**-1.6**	**-1.0**	**-0.2**					
PASS-MILES	1.05	**-1.4**	**-3.4**	**-4.1**	**-3.8**					
(% Change)	1.10	**-2.0**	**-3.8**	**-4.5**	**-5.0**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE FILE=I210WA-RPB2-FINAL

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
HOV VEHICLES	0.95	**0.0**	**0.0**	**0.0**	**8.9**					
AVG SPEED	1.00	**0.0**	**0.0**	**0.0**	**34.1**					
MPH	1.05	**0.0**	**0.0**	**0.3**	**77.7**					
(% Change)	1.10	**0.0**	**0.0**	**0.7**	**134.1**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE FILE=I210WA-RPB2

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
NON-HOV	0.95	**-5.4**	**-11.1**	**-16.2**	**-17.9**					
VEHICLE	1.00	**-3.4**	**-5.4**	**-20.0**	**-26.9**					
AVG SPEED	1.05	**-1.4**	**-8.0**	**-14.6**	**-21.9**					
MPH (% Change)	1.10	**-1.9**	**-6.8**	**-28.8**	**-11.8**					

Figure 5.30A Summary Effect of Demand Growth Level and 2+ Vehicle Percentages on Performance of Partial Barrier and Reduced Partial Barrier HOV Lane

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE										FILE=I210WA-RPB2-FINAL
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
TOTAL FUEL	0.95	**5.0**	**4.6**	**4.1**	**4.1**					
CONSUMED	1.00	**3.2**	**3.6**	**4.7**	**5.2**					
GALLONS	1.05	**3.3**	**2.8**	**2.7**	**3.3**					
(% Change)	1.10	**3.4**	**2.8**	**5.0**	**1.7**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE										FILE=I210WA-RPB2-FINAL
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
EMFAC2002	0.95	**4.2**	**5.1**	**5.2**	**4.9**					
TOTAL EMISSION	1.00	**1.3**	**2.9**	**6.2**	**7.5**					
KILOGRAMS	1.05	**1.9**	**1.9**	**2.8**	**3.8**					
(% Change)	1.10	**1.8**	**1.7**	**6.9**	**-0.1**					

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE										FILE=I210WA-RPB2-FINAL
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
FLOW LEVEL	0.95	**75-225**	**150-450**	**300-675**	**450-900**	**600-1125**	**650-1500**			
IN HOV LANE	1.00	**75-250**	**200-500**	**375-750**	**500-975**	**625-1200**	**700-1500**			
(VEHS/HOUR)	1.05	**100-275**	**225-550**	**575-825**	**525-1125**	**650-1350**				
	1.10	**100-300**	**250-600**	**600-850**	**550-1200**	**675-1500**				

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE										FILE=I210WA-RPB2-FINAL
MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
LEVEL OF	0.95	**N/H**	**N/H**	**N/M**	**N/M**	**N/M**	**L/M**			
FREEWAY	1.00	**N/H**	**N/H**	**N/H**	**N/H**	**N/H**	**M/M**			
CONGESTION	1.05	**N/H**	**N/H**	**N/H**	**N/H**	**N/H**				
	1.10	**N/H**	**N/H**	**N/H**	**N/H**	**N/H**				

X/Y = LEVEL OF FREEWAY CONGESTION : HOV LANE/NON-HOV LANES N= NONE L=LIGHT M=MODERATE H=HEAVY

Figure 5.30B Summary Effect of Demand Growth Level and 2+ Vehicle Percentages on Performance of Partial Barrier and Reduced Partial Barrier HOV Lane

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE FILE=I210WA-RPB2-FINAL

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
TOTAL FUEL	0.95	**31902**	**32011**	**32024**	**32004**	**31911**	**31822**			
CONSUMED	1.00	**32812**	**33248**	**33626**	**33851**	**33900**	**33724**			
(Gallons)	1.05	**33456**	**33903**	**34374**	**34855**	**35265**				
	1.10	**33961**	**34489**	**34979**	**35505**	**35929**				

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE FILE=I210WA-RPB2-FINAL

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
EMFAC2002	0.95	**2769**	**2758**	**2735**	**2703**	**2682**	**2663**			
TOTAL EMISSION	1.00	**2919**	**2932**	**2969**	**2971**	**2940**	**2909**			
(Kilograms)	1.05	**3015**	**3047**	**3078**	**3112**	**3137**				
	1.10	**3074**	**3114**	**3149**	**3188**	**3211**				

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE FILE=I210WA-RPB2-FINAL

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
TOTAL TIME	0.95	**14795**	**14594**	**14100**	**13440**	**13131**	**13322**			
AND DELAY	1.00	**18202**	**18019**	**19158**	**19027**	**18022**	**18714**			
(Pass-Hours)	1.05	**21502**	**21973**	**22526**	**23084**	**23439**				
	1.10	**23348**	**24045**	**24695**	**25387**	**25785**				

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE FILE=I210WA-RPB2-FINAL

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
TOTAL TRAVEL	0.95	**570330**	**602210**	**632835**	**660468**	**689340**	**718388**			
DISTANCE	1.00	**581384**	**619130**	**655840**	**693003**	**727154**	**756528**			
(Pass-Miles)	1.05	**576059**	**616537**	**656952**	**697689**	**738261**				
	1.10	**574112**	**616280**	**658138**	**700066**	**742164**				

Figure 5.30C Summary Effect of Demand Growth Level and 2+ Vehicle Percentages on Performance of Partial Barrier and Reduced Partial Barrier HOV Lane

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE FILE=I210WA-RPB2-FINAL

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
AVERAGE	0.95	**17.9**	**18.8**	**19.8**	**20.6**	**21.6**	**22.6**			
FUEL	1.00	**17.7**	**18.6**	**19.5**	**20.5**	**21.4**	**22.4**			
CONSUMPTION	1.05	**17.2**	**18.2**	**19.1**	**20.0**	**20.9**				
(Pass-Miles/Gal)	1.10	**16.9**	**17.9**	**18.8**	**19.7**	**20.7**				

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE FILE=I210WA-RPB2-FINAL

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
AVERAGE	0.95	**206**	**218**	**231**	**244**	**257**	**270**			
VEHICLE	1.00	**199**	**211**	**221**	**233**	**247**	**260**			
EMISSIONS	1.05	**191**	**202**	**213**	**224**	**235**				
(Pass-Miles/Kilo)	1.10	**187**	**198**	**209**	**220**	**231**				

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE FILE=I210WA-RPB2-FINAL

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
AVERAGE	0.95	**38.5**	**41.3**	**44.9**	**49.1**	**52.5**	**53.9**			
VEHICLE	1.00	**31.9**	**34.4**	**34.2**	**36.4**	**40.3**	**40.4**			
SPEEDS	1.05	**26.8**	**28.1**	**29.2**	**30.2**	**31.5**				
(mph)	1.10	**24.6**	**25.6**	**26.7**	**27.6**	**28.8**				

EFFECT OF DEMAND GROWTH LEVEL AND 2+ VEHICLE PERCENTAGES ON PERFORMANCE OF REDUCED PARTIAL BARRIER HOV LANE FILE=I210WA-RPB2-FINAL

MEASURE OF PERFORMANCE	GROWTH FACTOR	2+ HOV = 4%	2+ HOV = 8%	2+ HOV = 12%	2+ HOV = 16%	2+ HOV = 20%	2+ HOV = 24%	2+ HOV = 28%	2+ HOV = 32%	2+ HOV = 36%
HOV SPEED	0.95	**31.8**	**29.8**	**27.1**	**23.2**	**20.0**	**3.1**			
MINUS	1.00	**39.2**	**36.6**	**37.7**	**36.3**	**32.8**	**0.8**			
NON-HOV SPEED	1.05	**42.6**	**42.3**	**42.0**	**41.8**	**40.9**				
(mph)	1.10	**44.3**	**44.1**	**44.0**	**43.9**	**39.7**				

Figure 5.30D Summary Effect of Demand Growth Level and 2+ Vehicle Percentages on Performance of Partial Barrier and Reduced Partial Barrier HOV Lane

5.4. SUMMARY HIGHLIGHTS

This summary section describes the completed work on one task of the Caltrans' sponsored project "Determining the Effectiveness of HOV Lanes". This task, Task 4, was the "Application of the Modified FREQ Model to Evaluate HOV Lanes". The model was applied to two sites; one in District 04 and the other in District 07.

The modified FREQ model was applied to the I-580 freeway in the Dublin-Livermore area of District 04. The application was for the eastbound direction during the afternoon peak period utilizing 2004 freeway design and traffic count data. The study section was 28 miles long and the study period was from 2pm to 7pm. Currently there is no HOV lane in the study section but there is possible interest in adding a HOV lane. Two comprehensive sets of investigations were undertaken. Initially a full length HOV lane without an HOV barrier was investigated with a HOV lane use requirement of 3 or more persons per vehicle. Because of the relatively light usage of the HOV lane under some investigated situations, a second set of investigations was undertaken in which the HOV lane use requirement was changed to 2 or more persons per vehicle. The highlights of these two sets of investigation results are contained in the following Section 5.4.1.

The modified FREQ model was also applied to the I-210 freeway in the Pasadena area of District 07. The application was for the westbound direction during the morning peak period utilizing 2004 freeway design and traffic count data. The study section was 15 miles long and the study period was from 5:30am to 10:30am. Currently there is a full length HOV lane with intermittent HOV lane barriers that permits vehicles carrying two or more persons per vehicle to use the HOV lane. The first set of investigations was undertaken of the existing freeway situation but with varying the percentage of two or more persons per vehicle as well as engaging several levels of demand growth factors. It was felt desirable to vary these two important HOV parameters due to assumed vehicle occupancy distributions and limitations in the availability of traffic count data. Congestion was predicted in the HOV lane when higher percentages of two or more persons per vehicle were investigated. Because of the predicted congestion in the HOV lanes in a number of situations, a second set of investigations was undertaken. In the second set of investigations the number of access points to the HOV lane was reduced by extending some of the existing HOV barriers and thus reducing the usage of the HOV lane. The highlights of these two sets of investigation results are contained in the following Section 5.4.2.

The closing portion identifies some lessons learned in these applications of the modified FREQ model to evaluate HOV lanes

5.4.1 I-580 FREEWAY INVESTIGATION SUMMARY HIGHLIGHTS

The highlights of the I-580 investigation results for 3+ and 2+ HOV added lane scenarios are summarized in the following two sections.

5.4.1.1 Highlights of 3+ HOV Added Lane

The results obtained by adding an HOV lane with the assumed percentage of 3+ vehicles (5%) and using existing traffic demand levels indicated the following.

- The traffic flow in the HOV lane during the peak hour would reach 300 to 350 vehicles per hour and there was considerable excess capacity available for future growth of HOV lane users.

- Moderate to heavy congestion existed prior to the addition of an HOV lane. The addition of the HOV lane resulted in no congestion in the HOV lane and some minor congestion in the non-HOV lanes.
- The total passenger-hours were reduced by 20% and the total passenger-miles served during the peak period were increased by 1%.
- The total fuel consumption was increased by 1% while the total vehicle emissions were decreased by 1%, and
- The differential average speed over the length of the study section and study duration was predicted to be about 4 mph but varied considerable by time period and section of freeway.
- Anticipated future growth in traffic demands combined with anticipated greater utilization of the HOV lane resulted in greater benefits by implementing the HOV lane. The results predicted with a ten percent increase in traffic demand and an increased in percentage of 3+ vehicles from 5% to 7% indicated the following.
- The traffic flow in the HOV lane during the peak hour would increase from 300-350 vph to 500-550 vph and there was still considerable excess capacity available for further growth of HOV lane users.
- The addition of the HOV lane continued to result in no congestion in the HOV lane and an increase in level of congestion in the non-HOV lanes from light to moderate.
- The total passenger-hours were further reduced from 20% to 22% and the total passenger-miles served during the peak period were increased from 1% to 7% as compared to pre-HOV lane implementation.
- While total fuel consumption and total vehicle emissions increased with increased levels of traffic demand, the fuel consumption rate (passenger-miles per gallon) improved and the vehicle consumption rate (passenger-miles per kilogram) remained unchanged.
- The differential average speed over the length of the study section and duration was predicted to increase from 4 mph to 22 mph.

5.4.1.2 Highlights of 2 + HOV Added Lane

A second set of investigations were undertaken with all HOV design and operational parameters remaining the same except the HOV lane use occupancy requirement was changed from 3+ to 2+. The motivation for this set of further investigations was the concern for the low HOV lane usage (300-350 vehicles per hour) and the small differential speed (4 mph) obtained in the 3+ set of investigations with the base scenario investigation of 5% 3+ vehicle percentage and the existing traffic demand level.

The results obtained by adding an HOV lane with the assumed percentage of 2+ vehicles (20%), a HOV lane capacity of 1500 vph, and using existing demand levels indicated the following.

- The traffic flow in the HOV lane during the peak hour would reach 800 to 1500 vehicles per hour and there is little excess capacity for future growth of HOV lane users.
- Moderate to heavy congestion existed prior to the addition of an HOV lane. The addition of the HOV lane resulted in near-capacity operations in the HOV lane and no congestion in the non-HOV lanes.
- The total passenger-hours were reduced by 24% and the total passenger-miles served during the peak period were increased by 1%.
- The total fuel consumption was increased by 7% while the total vehicle emissions were increased by 4%.
- There was little difference between the average speed in the HOV lane and in the adjacent mixed-flow lanes.
- Anticipated future growth in traffic demands would overload the HOV lane.

- However after the modeling analysis was completed it was learned that District 04 uses a HOV lane capacity of 1650 vph rather than the model default HOV lane capacity of 1500 vph. It is estimated that the HOV lane could handle a two or three percent increase in 2+ vehicle occupancy percentage before the HOV lane would become congested if a HOV lane capacity of 1650 vph was modeled.

One method of increasing the size of the "window of opportunity" is by introducing intermittent barriers between the HOV and non-HOV lanes. The intermittent barriers were not investigated at this site because such barriers are not commonly used in this district and the limitation of time for further investigations. Investigations with an intermittent barrier were included in the second demonstration site in southern California.

5.4.2 I-210 FREEWAY INVESTIGATION SUMMARY HIGHLIGHTS

The highlights of the two sets of investigation results for the I-210 freeway are summarized in this portion of the chapter. The first set of analyses was directed to the evaluation of the impact that changes in 2+ HOV vehicle percentages and growth factors from the expected conditions would have on the performance predictions. The second set of analyses was directed to the evaluation of the impact of reducing the number of access points to the HOV lane on the performance predictions.

5.4.2.1 Impact of Changes in 2+ HOV Vehicle Percentages and Growth Factors

Because of the uncertainty in the vehicle occupancy distribution and the freeway traffic count information, an extensive set of sensitivity analyses were undertaken varying the 2+ HOV vehicle percentage from 4% to 36% and the traffic demand growth factors from 0.95 to 1.10. The results obtained with the assumed 2+ HOV vehicle percentage of 12% and a growth factor of 1.00 (assumed to be the base conditions) were compared with the results obtained with various levels of 2+ HOV vehicle percentages and growth factors.

The highlights of the findings of these analyses included the following:

- The assessment of on-freeway HOV lanes is significantly affected by 2+ HOV vehicle occupancy percentages and by the level of traffic demand.
- Congestion occurred in the HOV lane and queues from the HOV lane backed into the non-HOV lanes when the 2+ HOV vehicle occupancies reached 20% under growth factors from 0.95 to 1.10.
- Some congestion occurred in the HOV lane when the 2+ HOV vehicle occupancies reached 16% under growth factors from 0.95 to 1.10 and speeds in the HOV lanes were only slightly greater than speeds in the non-HOV lanes.
- The "best window of success" for the on-freeway HOV lane occurred when the 2+ HOV vehicle occupancy was 8% to 12%. The most significant results included the following:
    - No congestion occurred in the HOV lane
    - Speeds in the HOV lane were greater than speeds in the non-HOV lanes (19 to 42 mph) and provided encouragement for HOV vehicles to use the HOV lane and to motivate occupants of non-HOV vehicles to consider becoming HOV vehicle drivers or passengers.
    - Average fuel consumption rates (passenger-miles/gallon) and average vehicle emission rates (passenger-miles/kilogram) were among the best of the investigations analyzed.
    - Many of the results described for the 8% to 12% 2+ HOV vehicle occupancy levels were applicable to the 4% 2+ HOV vehicle occupancy level. However the traffic flow level in the HOV lane varied between 100 and 500 vph while the non-HOV lanes were highly

congested. There might be some concern about the HOV lane not being fully utilized while the other lanes were highly congested.

5.4.2.2 Impact of Reducing the Number of HOV Lane Access Points

A further set of investigations was undertaken because of the limited positive results obtained in the analysis of existing traffic demand levels and 2+ vehicle percentages of 16% and more as described in the previous section. One method of maintaining congested-flow operations in the HOV lane was to reduce the demand for the HOV lane by decreasing the number of access points to the HOV lane. This was accomplished by extending some of the existing intermittent barriers but maintaining an opportunity for I605 traffic to enter the HOV lane and for I210 traffic to exit from the HOV lane prior to the I210-SR134 interchange.

The highlights of the findings of these analyses included the following:

- Congestion occurred in the HOV lane and queues from the HOV lane backed into the non-HOV lanes when the 2+ HOV vehicle occupancies reached 28% under growth factors from 0.95 to 1.10.
- Congestion occurred in the HOV lane when the 2+ HOV vehicle percentage was 24% with growth factors from 0.95 to 1.00 and queues backed into the non-HOV lanes when the growth factor was greater than 1.05 or greater. The speeds in the HOV lane were significantly greater than speeds in the non-HOV lanes.
- Congestion did not occur in the HOV lane when the 2+ HOV vehicle percentage was less than 24%. The speeds in the HOV lane were significantly greater than speeds in the non-HOV lanes.
- However in comparison with the existing intermittent barrier design: total passenger-hours increased, total passenger-miles served decreased, total fuel consumption increased, and total vehicle emissions increased in all combinations of 2+ vehicle percentages and demand levels investigated. This was due to the much higher levels of congestion in the non-HOV lanes.
- The bottom line was that reduction of the number of access points to the HOV lane did provide for improved operations in the HOV lane and maintained a speed differential significantly favoring the HOV lane users. However in terms of the combined performance of both the HOV lane and the non-HOV lanes, the consequences were negative.
- It is anticipated that further demand growth will result in the HOV lane becoming congested and the non-HOV lanes becoming severely congested.

5.4.3 GENERAL SUMMARY HIGHLIGHTS

A number of lessons were learned from these two HOV freeway investigations and highlights include the following:

- Vehicle occupancy distributions have a very significant effect on the performance of on-freeway HOV lane facilities. Accurate data on vehicle occupancy distributions is essential for the realistic modeling of such facilities.
- Traffic demand levels have a very significant effect on the performance of an on-freeway HOV lane facility. Modeling of HOV facilities should include both current and future traffic demand levels. Current comprehensive traffic counts should be accurately measured and future traffic demands predicted with care.
- The FREQ model was well suited for investigating on-freeway HOV lane facilities. The model was very flexible in modeling various combinations of HOV lane design and operational parameters and providing a wide variety of measures of performance.

- In both cases the length of the freeway study section and the duration of the peak period were not adequate to include the total impacts of the HOV lane facility. Greater attention is needed to design the modeling to completely encompass the impacts of HOV lane facilities under current and future traffic conditions.
- The design of a successful HOV lane facility is a very difficult task and requires careful analyses prior to implementation in order to move toward an optimum design. Future increases in freeway traffic demands and increases in the percent of HOV lane users due to good HOV lane operations are likely to require changes in the HOV lane design and operational parameters over time. This will require careful monitoring the operations of HOV lane facility and further modeling analyses.

CHAPTER SIX

DEVELOPMENT OF OFF-LINE PeMS MODULE FOR ESTIMATING AIR QUALITY

6.1 INTRODUCTION

6.1.1 Objective

The objective of Task Five was to develop and demonstrate an off-line methodology to be used with the Performance Measurement System (PeMS) to provide air quality estimates.

6.1.2 The PeMS Software

The Performance Measurement System (PeMS) is a traffic data collection, processing, and analysis tool designed to assist traffic engineers in assessing the performance of freeway systems. Developed jointly by Caltrans, the University of California at Berkeley, and the Partnership for Advanced Technology on the Highways (PATH), PeMS obtains real-time, 30-second loop detector data on counts (number of vehicles crossing the loop) and occupancy (the average fraction of time a vehicle is present over the loop) and presents this information in various forms to traffic engineers, planners, freeway users, researchers, and travel information services.

6.1.3 Proposed Module Development

The current PeMS data base provides on-line traffic performance information such as flows, percent occupancies, densities, and speeds for many freeway stations in California. However, it does not include air quality projections. On the basis of the literature review and the modified air quality projections in the FREQ model, the project team developed a methodology to estimate air quality as part of the PeMS data base. This off-line methodology was tested and demonstrated on the Southern California roadway, I 210 W, that was part of the Task Four evaluation, and is available to future projects for possible later implementation.

6.2 OVERVIEW

A conceptual overview of the off-line methodology appears in Figure 1. This Figure outlines the basic PeMS processing steps, along with the additional steps recommended for estimating pollutant levels off-line. A brief discussion of each off-line box outside the basic PeMS processing module follows.

- Emission rate tables for three pollutants, HC, CO, and NO_x were developed using the latest version of the California Air Resources Board emissions model, EMFAC2002. These tables contain emission rates in grams per mile at a given speed from 5 to 70 miles per hour in increments of 5 miles per hour.

- Next, the amounts of pollutants generated for each loop detector segment are computed.

- For each loop detector (i), a loop detector segment (i) is defined. The end points of loop detector segment (i) are half the distance between the detector (i) and the next detector upstream (i-1) and half the distance between the detector (i) and the next detector downstream (i+1)

- For each pollutant, the five-minute speed data from PeMS at a specific loop detector (i) and lane (j) are used to extract the appropriate emission rate from the emission rate table. Emission rates between table entries are estimated by interpolation.

- For each pollutant, the emissions in grams are calculated for each loop detector segment (i) for each lane (j) as a function of the volume data from PeMS at loop detector (i), the length of loop detector segment (i), and the emission rate (i,j) for the speed at loop detector (i) for lane (j).

- The five-minute lane-by-lane data are summed across lanes to form an aggregate value for the traffic on a particular freeway segment. These aggregate segment values for each of the three pollutants are used in summing emissions over space and time.

- Aggregated segment values are summed spatially across all segments within the boundaries of a particular length of freeway, producing aggregate emissions for HC, CO, and NO_x in five-minute slices.

- Five-minute data slices for the freeway study length are summed to produce peak-hour data values.

- Five-minute data values are aggregated to produce peak-period estimates of the number of grams of the pollutants HC, CO, and NO_x produced over the selected length of freeway.

6.3 COMPUTATION ISSUES

The developed methodology makes assumptions about two key issues, sampling rate and vehicle mix, that merit additional comment. The impact that the spacing of detector stations and the PeMS data quality have on the predicted emissions is also discussed.

6.3.1 Sampling Rate.

One issue to be addressed in developing a methodology for using PeMS data to estimate air quality is the appropriate sampling rate. Some applications of the PeMS data base (notably the RTMIS data base developed by the Southern California Association of Governments) aggregate data on a one-hour basis. Obviously, an average speed of 40 mph over one hour will have different air quality consequences depending on whether it was a consistent 40 mph or 30 minutes at 60 mph and 30 minutes at 20 mph. For this reason, we recommend using the five-minute samples produced by the PeMS processing module as a basis for computing emissions, and then summing the five-minute emissions to obtain one-hour and twenty-four hour estimates.

In theory, it would be possible to break pollution rates down even more finely by computing 30-second emissions, but this would require entering the PeMS processing unit before the module has adjusted the raw data readings to take account of missing data, bad loops, and suspect data elements.

6.3.2 Vehicle Mix

The official model for evaluating on-freeway vehicle emission in California is EMFAC, which was developed and continues to be updated by the California State Air Resources Board (ARB). The latest version of this model, EMFAC2002 was used by the research team to develop emission rate tables for the FREQ freeway simulation model as part of Task 3 of this project, and these tables were subsequently used in developing emission rate tables for the PeMS off-line air quality module.

EMFAC2002 produces emission rates for 13 vehicle classes. The 8 different truck classes are defined by weight, and further subdivided by non-catalytic, catalytic, or diesel. The vehicle mix reported in the PeMS database consists of two vehicle classes: trucks that are over 60 feet in length and the remainder of the vehicles.

For the purpose of demonstrating a technique for estimating emissions using the PeMS database, it was decided that one state-wide-average emission rate table representing the entire vehicle fleet for California freeways would be developed for each of the three pollutants: total hydrocarbons, carbon monoxides, and oxides of nitrogen. The freeway vehicle mix that was recommended by the ARB staff for Task 3 was also used for the off-line PeMS module. If the methodology developed for the off-line air quality module is eventually incorporated into the PeMS database, consideration might be given to developing two sets of emission rate tables, one for each of the two vehicle classes identified in PeMS. To do this, a correspondence would need to be established between the thirteen vehicle classes plus subclasses in EMFAC2002 and the two vehicle classes in PeMS. It would also be possible to develop emission rate tables that are calculated for specific geographical regions. Both of these options were beyond the scope of the current project.

6.3.3 Spacing of Detector Stations

The spacing of detector stations will affect the accuracy of the air quality estimates. For a particular detector, the proposed methodology imputes a single lane-dependent speed to all vehicles over a freeway segment that stretches half the distance to the next detector upstream and half the distance to the next detector downstream. In practice, these distances can vary from 0.5 miles to 2 miles in length. Clearly, speeds are more likely to vary over detector segments as the distance between successive detector stations lengthens. Such speed variations will lower the accuracy of the air quality estimates. The extent to which lengthened detector segments will affect the accuracy of air quality estimates would make an instructive topic for future research.

6.3.4 Data Quality

Clearly, the quality of emission predictions can be no better than the quality of the basic PeMS data supporting those predictions. PeMS data quality will be affected by defective or inoperative detector loops and stations. The PeMS program performs diagnostics on individual detector loops every day. When a detector is identified as bad, the information is reported to users and imputation algorithms are used to fill in any data gaps. (This process is graphed in the PeMS Processing Module diagrammed in Figure One.) The reported quality of loop detectors was noted and taken into account in selecting a demonstration route and developing emission predictions along that route.

6.4 DEMONSTRATION

6.4.1 Location

The developed off-line methodology was applied to the same 14.1 mile length of I 210 W in Southern California used in the FREQ evaluation of Task Four.

6.4.2 Approach

In Task Three, the project team developed computerized tables relating particle emissions of HC, CO, and NOx to vehicle speeds for the current year assuming temperatures of 75 degrees (F) and humidity of 40%. These tables related emission rates (in grams per vehicle mile) to speeds in 5-mph increments between 5-mph and 80mph. For the current task, the team developed a program to interpolate emission rates at speeds between 5-mph increments and applied this program to a data base recording historical PeMS data on the I-210 W study area. This data base documented the speeds and traffic flows for each of the twenty-two identified loop detector stations along the I-210 W study section in five-minute increments for the date of April 10, 2006.

6.4.3 Single Segment Computations

As a first step in demonstrating the proposed off-line methodology, the project team computed the emissions produced along a single freeway segment, the westernmost segment of the I-210 W study section, for each of the five-minute increments recorded by loop detectors on April 10. These detectors covered the HOV lane and four mainline lanes at the station designated as FAIROAKS 1 by CALTRANS. Emission summaries for the peak morning hour (8 am to 9 am) over the .14 mile section of freeway centered on this station are summarized in Figure 2.

6.4.4 Road Section Computations

To extend the developed methodology to the entire I-210 W study section, the project team computed the emissions produced along the full length of the I-210 W study section, for each of the five-minute increments recorded by loop detectors at each of the twenty-two detector stations on April 10. Emissions at the twenty-two stations were then aggregated for the peak morning hour, the peak morning period, and the entire day. Emission summaries for these time periods appear in Figures 3 and 4.

6.4.5 1-mph—5-mph Comparison

The off-line methodology was demonstrated using computerized tables that related particle emissions of HC, CO, and NOx to vehicle speeds in 5 mph increments between 5 mph and 80 mph. These increments were consistent with those used in the FREQ of Task Four.

As the methodology was being demonstrated, the project team wondered whether speed tables reflecting 1 mph increments might represent a significant improvement in particle estimation. To explore this possibility, the team developed computerized tables relating particle emissions of HC, CO, and NOx to vehicle speeds in 1 mph increments between 5-mph and 80mph, along with a routine to interpolate emission rates at 1 mph increments. These denser particle curves were applied to one of the locations along the I-210 W study section.

The tables shown in Figure 5 compare emission rates calculated at 1-mph and 5-mph intervals for the I-210 W HOV lane at the Altadena Station (MP 28.03). For the peak travel hour between 7 am and 8 am, the particle estimates provided by the 5-mph tables were slightly higher than the rates computed using the 1-mph tables. In terms of percentages, the HC estimates were 0.34% higher, the CO estimates were 0.19% higher, and the NOx estimates were 0.22% higher.

Examination of each of the 5-minute data intervals over the 24-hour period on April 10 showed that particle estimates made using 5-mph increments were consistently higher or equal to the estimates made using 1-mph increments, reflecting the concave nature of the curves themselves. Differences for the 5-minute intervals never exceeded 0.94%, and averaged 0.41% for HC, 0.34% for CO, and 0.41% for NOx.

These differences were judged to be small enough to justify the continued use of 5-mph increments in calculating emissions using the FREQ program. However, the developed off-line methodology is capable of accommodating either 1-mph or 5-mph increments.

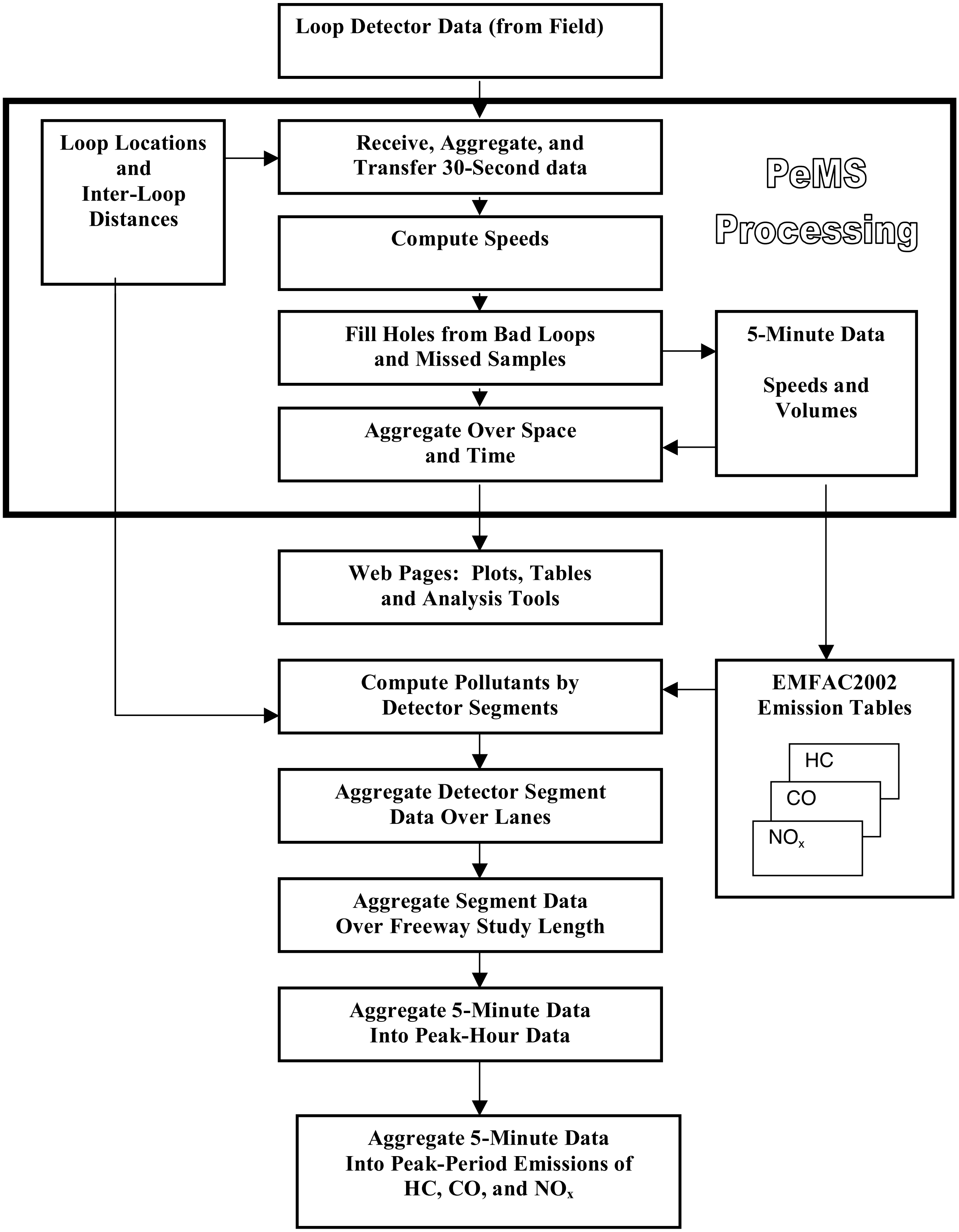


Figure 6.1 Overview of Computation Process

PEAK HOUR EMISSIONS (GRAMS)

LOCATION:	FAIROAKS 1	MILEPOST:	25.4
MAINLINE LANES:	4	SECTION :	.14 mi

TIME	**TOTAL HYDRO-CARBONS**	**CARBON MONOXIDE**	**OXIDES OF NITROGEN**
MAINLINE LANES			
8:00	26.463	287.577	90.293
8:05	27.681	301.114	94.040
8:10	27.650	300.195	94.791
8:15	28.509	311.701	95.916
8:20	29.841	323.239	105.469
8:25	27.319	298.436	93.267
8:30	26.451	286.974	94.154
8:35	26.875	290.796	95.657
8:40	27.323	296.935	94.817
8:45	27.702	301.269	94.668
8:50	26.769	292.438	92.180
8:55	26.448	288.979	90.428
TOTAL	329.029	3579.651	1135.682
HOV LANE			
8:00	2.486	27.612	8.231
8:05	2.498	27.700	8.290
8:10	2.391	26.496	7.941
8:15	2.336	25.880	7.756
8:20	2.324	25.799	7.700
8:25	2.375	26.385	7.865
8:30	2.268	25.184	7.517
8:35	2.272	25.211	7.535
8:40	2.280	25.264	7.572
8:45	2.221	24.622	7.369
8:50	2.169	24.031	7.202
8:55	2.176	24.082	7.237
TOTAL	27.796	308.266	92.215
FREEWAY TOTAL	356.825	3887.917	1227.897

Figure 6.2 Peak Hour Emissions At Fairoaks One Location

PEAK HOUR EMISSIONS (GRAMS)

LOCATION:	I-210 W	MP 39.5	TO	MP 25.4
DATE:	4/10/06			

MAINLINE LANES	VEH-MI	HYDRO-CARBONS	CARBON MONOXIDE	OXIDES OF NITROGEN
TIME				
7:00 AM	8885.45	3401.23	36938.45	9931.67
7:05 AM	8951.96	3440.84	37026.32	9668.57
7:10 AM	9117.08	3660.91	38836.49	10269.44
7:15 AM	8867.93	3651.05	38305.39	10140.79
7:20 AM	8667.51	3686.85	37726.82	9831.72
7:25 AM	8780.18	3689.46	37457.06	9643.15
7:30 AM	8893.78	3837.84	38199.68	9599.43
7:35 AM	9104.95	3964.13	39735.89	10120.43
7:40 AM	9088.74	3884.39	39294.67	9760.49
7:45 AM	9172.75	3729.55	38916.88	9714.38
7:50 AM	9202.80	3934.08	40289.46	9941.54
7:55 AM	9243.14	3861.00	40061.90	9920.98
SUB-TOTAL	107976.28	44741.33	462789.02	118542.59
PER VEH MILE		0.414	4.286	1.098
HOV LANE				
7:00 AM	1475.24	658.99	6979.55	1551.96
7:05 AM	1481.18	688.95	7140.88	1572.94
7:10 AM	1480.49	692.27	7168.62	1582.35
7:15 AM	1436.98	687.11	7005.23	1555.93
7:20 AM	1421.98	685.43	6958.19	1539.19
7:25 AM	1365.49	662.95	6713.93	1488.48
7:30 AM	1401.77	690.73	6946.35	1498.72
7:35 AM	1491.43	736.34	7361.22	1615.68
7:40 AM	1415.89	746.70	7250.28	1537.08
7:45 AM	1395.98	674.61	6899.50	1486.83
7:50 AM	1450.54	707.27	7193.27	1550.01
7:55 AM	1488.46	698.15	7223.06	1573.79
SUB-TOTAL	17305.41	8329.50	84840.08	18552.96
PER VEH MILE		0.481	4.903	1.072
TOTAL FREEWAY	125281.69	53070.83	547629.10	137095.55
PER VEH MILE		0.424	4.371	1.094

Figure 6.3 I-210 West Peak Hour Emissions

PEAK PERIOD EMISSIONS (GRAMS)

LOCATION:	I-210 W	MP 39.5	TO	MP 25.4
DATE:	4/10/06			

MAINLINE LANES	VEH-MI	HYDRO-CARBONS	CARBON MONOXIDE	OXIDES OF NITROGEN
TIME				
6:00 TO 7:00 AM	110389.92	40027.76	446030.21	132470.18
7:00 TO 8:00 AM	107976.28	44741.33	462789.02	118542.59
8:00 TO 9:00 AM	97596.93	41429.53	436927.44	107529.52
9:00 TO 10:00 AM	97948.43	36488.61	402743.81	117291.65
SUB-TOTAL	413911.56	162687.23	1748490.48	475833.95
PER VEH MILE		0.393	4.224	1.150
HOV LANE				
6:00 TO 7:00 AM	17187.34	6554.49	73201.91	18831.58
7:00 TO 8:00 AM	17305.41	8329.50	84840.08	18552.96
8:00 TO 9:00 AM	16156.54	6634.88	71854.64	16452.58
9:00 TO 10:00 AM	11889.18	4649.67	52253.74	14506.35
SUB-TOTAL	62538.47	26168.54	282150.37	68343.46
PER VEH MILE		0.418	4.512	1.093
TOTAL FREEWAY	476450.03	188855.76	2030640.85	544177.41
PER VEH MILE		0.396	4.262	1.142

24-HOUR EMISSIONS (GRAMS)

	VEH-MI	HYDRO-CARBONS	CARBON MONOXIDE	OXIDES OF NITROGEN
MAINLINE LANES	1642109.04	649869.537	7168178.03	2250088.34
HOV LANE	197661.39	77961.59	848986.99	240599.13
TOTAL FREEWAY	1839770.43	727831.12	8017165.02	2490687.48
PER VEH MILE		0.396	4.358	1.354

Figure 6.4 I-210 W Peak Period And 24-Hour Emissions

HOV LANE PEAK HOUR EMISSIONS (GRAMS)

LOCATION:	I-210 W	MILE POST	28.03	(ALTADENA)
DATE:	4/10/06	LENGTH:	.735 MILES	

1 MPH TABLES

TIME	VEH-MI	HYDRO-CARBONS	CARBON MONOXIDE	OXIDES OF NITROGEN
7:00 AM	68.36	24.718	285.392	77.285
7:05 AM	69.83	25.200	291.364	78.543
7:10 AM	81.59	29.331	340.118	90.702
7:15 AM	82.32	29.650	343.307	92.122
7:20 AM	69.83	25.034	290.974	76.749
7:25 AM	68.36	24.653	285.176	76.758
7:30 AM	83.79	30.408	355.594	85.813
7:35 AM	93.35	33.710	394.543	96.207
7:40 AM	86.00	33.722	384.663	85.142
7:45 AM	72.03	30.944	340.148	71.285
7:50 AM	84.53	33.146	378.088	83.687
7:55 AM	82.32	31.350	361.608	81.965
SUB-TOTAL	942.27	351.87	4050.97	996.26
PER VEH MILE		0.373	4.299	1.057

5 MPH TABLES

TIME	VEH-MI	HYDRO-CARBONS	CARBON MONOXIDE	OXIDES OF NITROGEN
7:00 AM	68.36	24.843	286.423	77.600
7:05 AM	69.83	25.317	292.299	78.824
7:10 AM	81.59	29.416	340.754	90.887
7:15 AM	82.32	29.776	344.270	92.405
7:20 AM	69.83	25.034	290.974	76.749
7:25 AM	68.36	24.764	286.052	77.020
7:30 AM	83.79	30.497	356.149	85.960
7:35 AM	93.35	33.722	394.620	96.227
7:40 AM	86.00	33.902	385.655	85.411
7:45 AM	72.03	31.105	340.849	71.451
7:50 AM	84.53	33.322	379.063	83.951
7:55 AM	82.32	31.364	361.675	81.983
SUB-TOTAL	942.27	353.06	4058.78	998.47
PER VEH MILE		0.375	4.307	1.060
1 MPH - 5 MPH		-1.20	-7.81	-2.21
% DIFFERENCE		-0.34%	-0.19%	-0.22%

Figure 6.5 1-Mph/5-Mph Increment Comparison

CHAPTER SEVEN

CONCLUSION

7.1 OVERVIEW

This chapter summarizes the key analytic approaches undertaken in the current investigation of the effectiveness of HOV lanes and highlights the conclusions of the various analyses. The chapter is divided into three subsections as follows:

1. Performance of California HOV Lanes (Task Two);
2. Assessing, Developing, and Demonstrating Methods for Modeling Air Quality (Tasks Three and Five); and
3. Application of the Modified FREQ Model to HOV Lane Evaluation (Task Four).

7.2 PERFORMANCE OF CALIFORNIA HOV LANES

7.2.1 Historical Trends

Growth of Ridesharing. Figure 7.1 plots the growth in the incidence of ridesharing on State Route 99 in District 3 from the introduction of the HOV lanes in November 1990 through 2003.

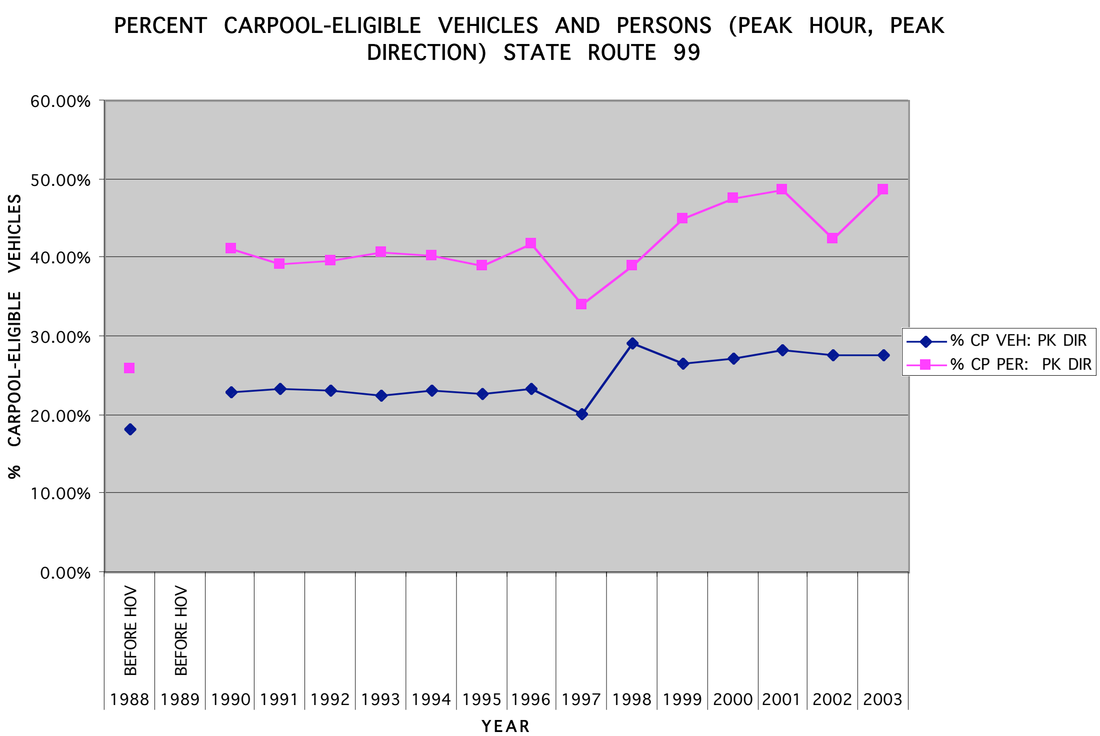


Figure 7.1 Percentage Of Carpool-Eligible Vehicles And Persons Using State Route 99 During The Peak Morning And Evening Hours

The graph of Figure 7.1 reflects the growth pattern typical of most HOV lanes in California. The introduction of HOV lanes has been followed by an initial jump in the incidence of carpooling, followed by a leveling and a steady growth over time. When HOV lanes were introduced in November 1990 on State Route 99, the percentage of vehicles carrying two or more persons during the peak hour jumped from 18.3% to 22.8%, while the number of people in these vehicles jumped from 26.0% of those using the freeway to 41.1%. The incidence of ridesharing vehicles and persons held fairly steady for seven years, and then rose again following the lengthening of the HOV lanes in 1997. By 2003, the incidence of vehicles carrying two or more persons had risen to 27.7%, just over one quarter of the peak-hour traffic, while the number of persons in these vehicles had risen to 48.7% of all those using the freeway.

<u>Changes in Time Savings.</u> Figure 7.2 shows the travel times in the southbound HOV lane and adjacent mixed flow lanes on State Route 99 from1990 through 2003. When the HOV lanes were first introduced, the time savings available over their 3.9 mile length were relatively small—amounting to less than one minute. As congestion increased in the mixed flow lanes, the available time savings jumped to 4 minutes in 1995, and rose again to 5.5 minutes in 1997, when the length of the HOV lanes was extended from 3.9 miles to 9.7 miles. By 2003, the recorded savings had risen to 6.67 minutes, or just under a half minute per mile over the 14.3 mile length of the lanes.

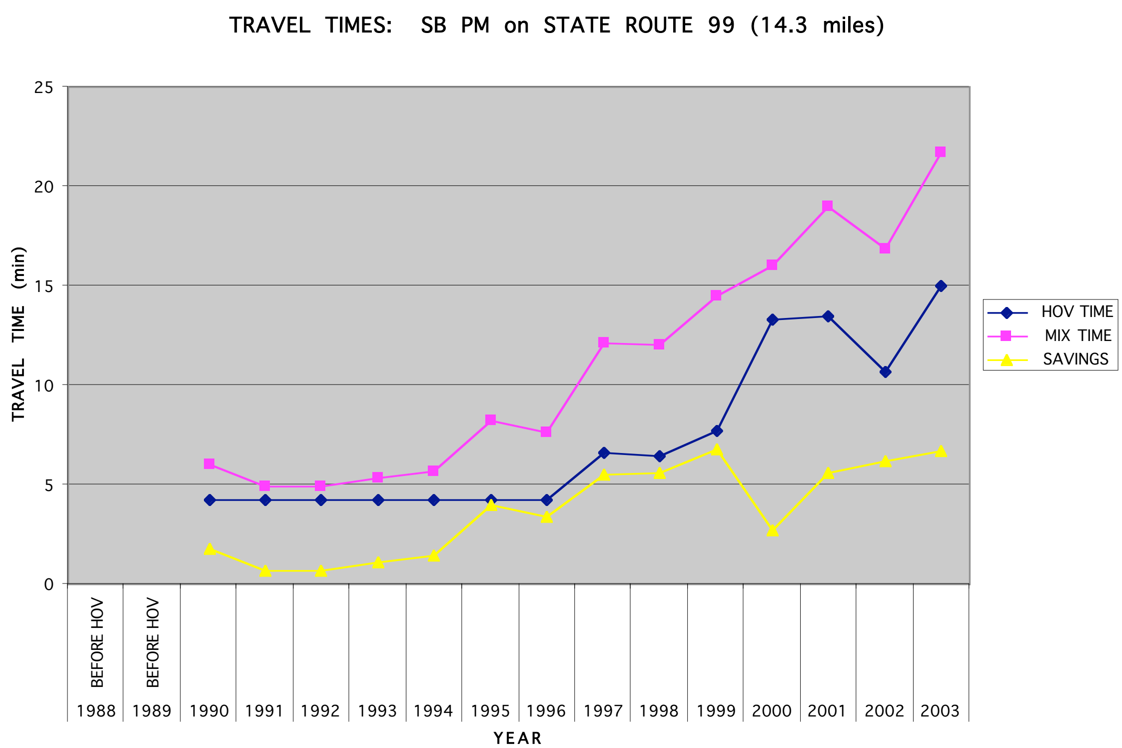


Figure 7.2 Travel Time Savings—SB PM On SR 99

While consistent statistics on the time savings afforded by HOV lanes proved to be one of the most difficult pieces of historical data to obtain, the experience plotted in Figure 7.2, in which time savings increase over time as congestion in mixed-flow lanes increases, appears to be typical.

Carpools on HOV and Non-HOV Freeways. Figure 7.3 plots the growth of carpools on HOV and non-HOV freeways in District Seven during the two peak morning hours between 1992 and 2003. The figure shows an immediate growth in carpooling in the years 1993 and 1994, which saw 121.4 new HOV lane miles introduced on LA-91, I-105, I-210, and I-405. The average number of carpools on district freeways then leveled off, but began rising steadily between 1997 and 2003.

The steady increase in carpooling between 1997 and 2003 was fueled almost exclusively by increases on freeways with carpool lanes, as Figure 7.3 shows a decline in the average number of carpools on non-HOV freeways over that same period.

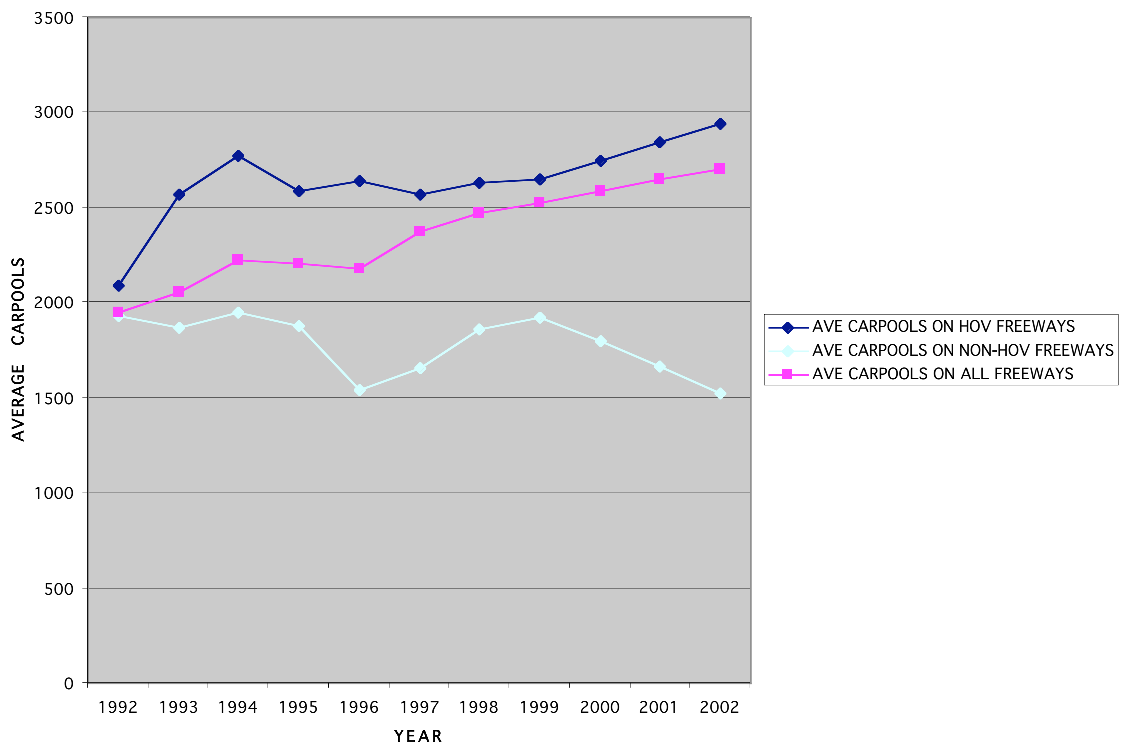
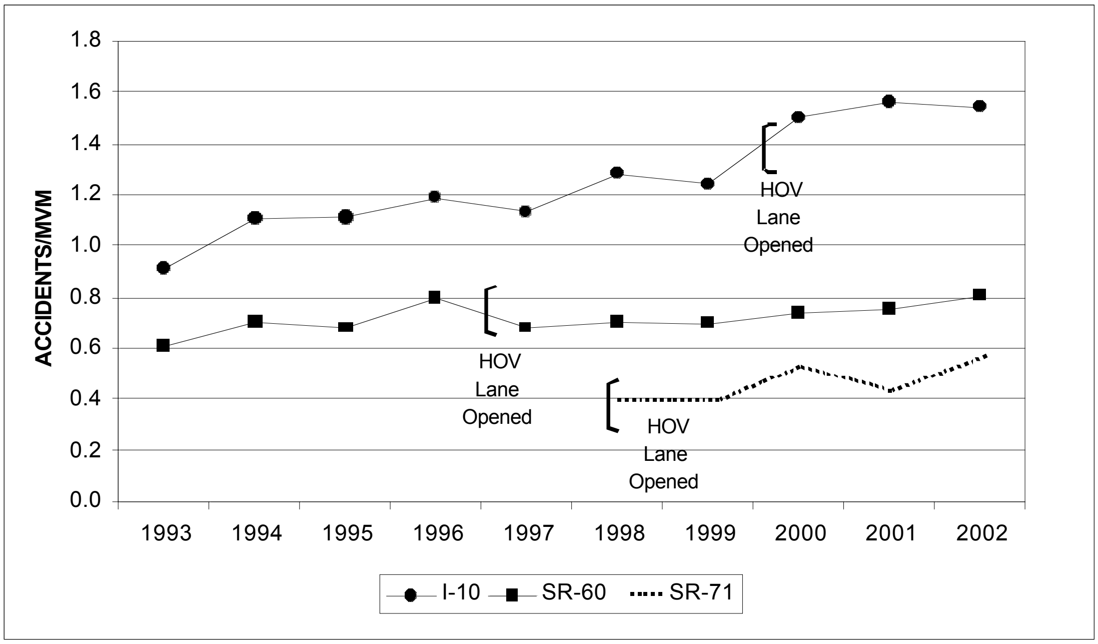


Figure 7.3 Carpools Over Time On HOV And Non-HOV Freeways (Two Peak Morning Hours in District Seven)

Accidents Over Time. The question of safety is one of the most vexing associated with HOV lane operations and analysis, and the issue most in need of serious research. On some projects, such as the Santa Monica Diamond Lanes and Route 237 in Santa Clara, California, accident rates have increased significantly following the introduction of HOV lanes. Yet other concurrent flow lanes have been installed with no increase in accidents. Attempts to investigate the impact of specific design features on accident rates have been frustrated by a number of factors, primarily the lack of valid data prior to lane installation.

Accidents on Three San Bernardino Routes. Figure 7.4 graphs historical accident rates on three mainline HOV lanes in San Bernardino County: I-10, SR-60, and SR-71. The graph shows that the accident rate on the affected stretch of Interstate 10 increased significantly after HOV lanes were opened in January 2000 and has continued at an increases rate (35% higher than pre-HOV rates) ever since. In the case of SR-60 paralleling I-10, however, the opening of HOV lanes did not cause a significant change in the accident rate over the affected stretch of freeway.

In the case of State Route 71, HOV lanes were opened at the same time the new freeway was built, so that there are no before/after accident statistics. Accident rates on SR-71 are lower than those recorded on any nearby routes, presumably reflecting lower congestion levels and lower levels of HOV lane utilization.



Source: TASAS, SYSTAN, June 2005.

Figure 7.4 Accident Rates On San Bernardino County Freeways With HOV Lanes

The experience of the three District Eight routes with accident rates is typical. In some cases, accidents have increased significantly following the introduction of HOV lanes (as on I-10). In other cases, however, the implementation of HOV lanes has had no apparent impact on accidents. In the absence of more detailed studies, therefore, the effect of HOV lanes on safety remains somewhat problematic. While carpool lanes on freeways affect congestion and weaving patterns in ways that mixed-flow lanes do not, there is no conclusive evidence that mainline HOV lanes consistently raise or lower accident rates.

Accidents on Orange County HOV-to-HOV Connectors. While nothing conclusive can be said about the impact of mainline HOV lanes on accidents, one type of HOV facility appears to reduce accident rates consistently. The installation of freeway-to-freeway connectors linking Orange County's HOV lanes has consistently resulted in a decrease in accident rates in the vicinity of the freeway intersection. A recent SCAG study (SYSTAN 2005) concluded that the installation of direct HOV-to-HOV connectors almost universally reduced accident rates in the vicinity of the affected intersections, achieving rate reductions ranging from 7% to 33%.

7.2.2 Current Performance

<u>HOV Lane Volumes</u>. Figure 7.5 plots the average HOV lane usage in each CALTRANS District.

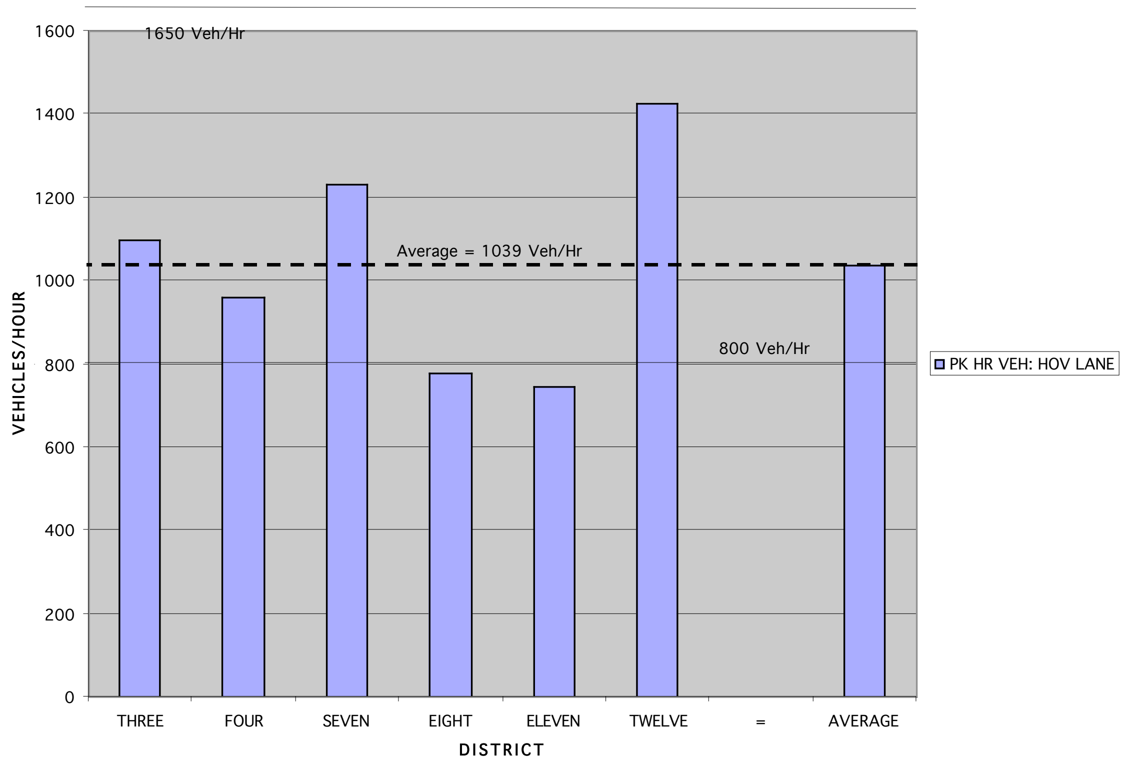


Figure 7.5 Average Hov Lane Flow By District (Vehicles Per Peak Hour)

The bold horizontal lines of Figure 7.5 represent two generally recognized measures of performance for HOV lanes.

(1) The lower level of 800 vehicles per hour, which is generally recognized as the minimum operating standard for a mature HOV lane (HOV Systems Manual, NCHRP Report 414). Operations below this level can experience the "empty lane syndrome" at which lanes appear underutilized.

(2) The upper level of 1650 vehicles per hour, at which point free-flow operations can begin to deteriorate, causing the time advantage offered by the HOV lanes to disappear. (Parsons Brinckerhoff, 2002)

As indicated in Figure 7.5, the HOV freeway lanes in most CALTRANS Districts easily exceed the minimum operating standard of 800 vehicles per hour. Lanes in Districts Eight and Eleven were slightly below this standard, but in each case the average was dragged down by recently constructed HOV lanes on relatively uncongested freeways. The average peak hour flow on all California HOV lanes was 1039 vehicles per hour in 2004, so there is little danger that the district's HOV lanes will fall victim to the "empty lane syndrome." In fact, individual \ HOV lanes in District Twelve exceeded the upper limit of 1650 vehicles per hour at two locations. On the whole, California's HOV lanes are well utilized during peak commute hours.

Person Volumes. Figure 7.6 compares the percentage of freeway person trips carried by California's HOV lanes and adjacent mixed-flow lanes in the peak direction of flow during the peak commute hours.

(2003: Peak Hour, Peak Direction)

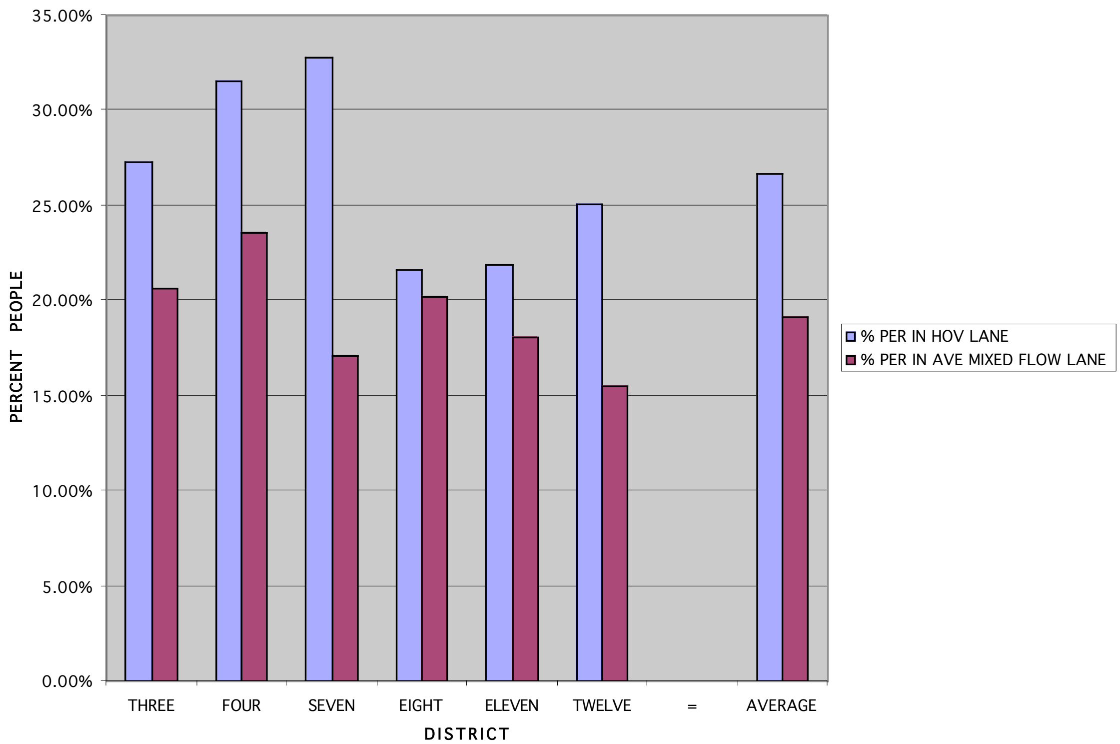


Figure 7.6 Percent Persons in HOV and Average Adjacent Mixed-Flow Lanes

As would be expected, in every district, the average percentage of freeway travelers carried by the HOV lanes is significantly greater than the percentage carried by the average adjacent mixed-flow lane. On the average, California's HOV lanes carry 26.7% of the people in HOV corridors, while the average adjacent mixed-flow lane carries only 19.2%. Except on the El Monte Busway in District Seven, where the HOV lane carried 50% of all people traveling on the freeway during the evening peak, the predominant person-carrying capacity of the HOV lanes is achieved through carpools, with relatively small contributions from buses.

Travel Time Savings. Figure 7.7 graphs the average time savings available the HOV freeway network in each CALTRANS District. Time savings were calculated by comparing the travel times of vehicles traveling the entire length of individual HOV lanes with the corresponding times recorded by vehicles in adjacent mixed-flow lanes.

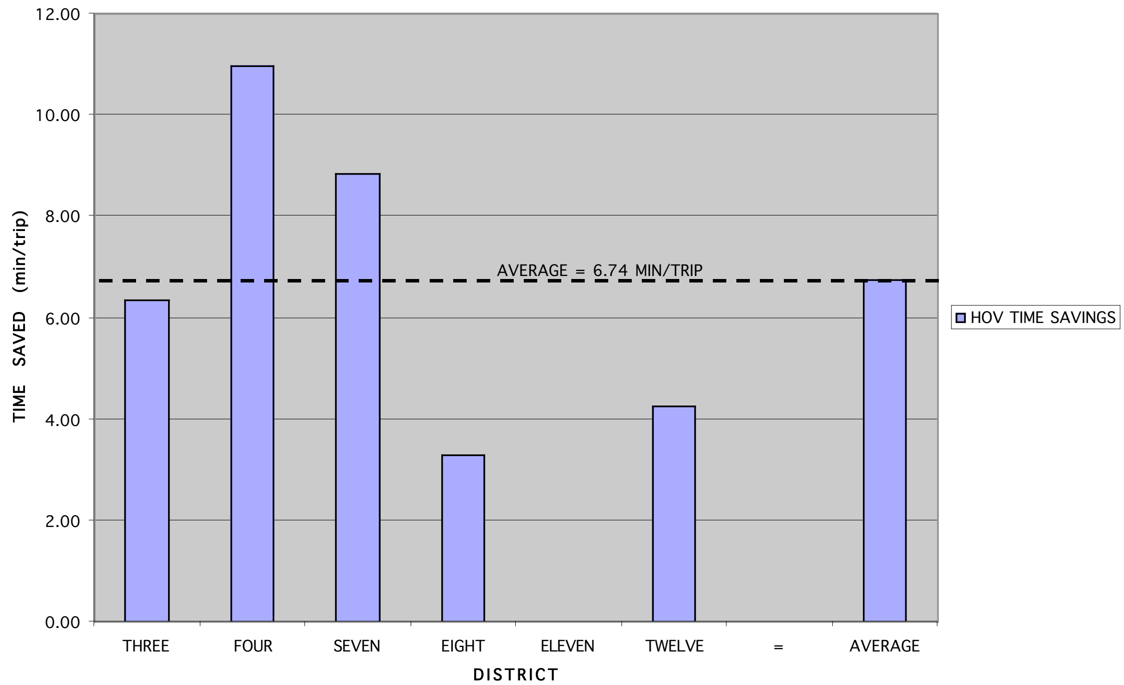


Figure 7.7 HOV Lane Time Savings (Peak Hour, Peak Direction)

The HOV Systems Manual (NCHRP Report 414) suggests that a savings goal of five minutes per trip, and/or one minute per lane mile, be used to gauge the success of HOV lane operations. As shown in Figure 7.7, the average time savings for all District HOV lanes recorded in 2003 was 6.7 minutes (0.56 minutes per mile), well above the five-minute success threshold defined in the HOV Systems Manual. The relatively low time savings recorded in District Twelve reflects HOV lane congestion around Orange County's "Orange Crush," where Freeways SR-57, I-5, and SR-22 meet. In the vicinity of this crush, drivers using the mixed-flow lanes actually travel faster than carpoolers.

Violation Rates. Figure 7.8 plots the average violation rates recorded on the HOV lanes in each CALTRANS District.

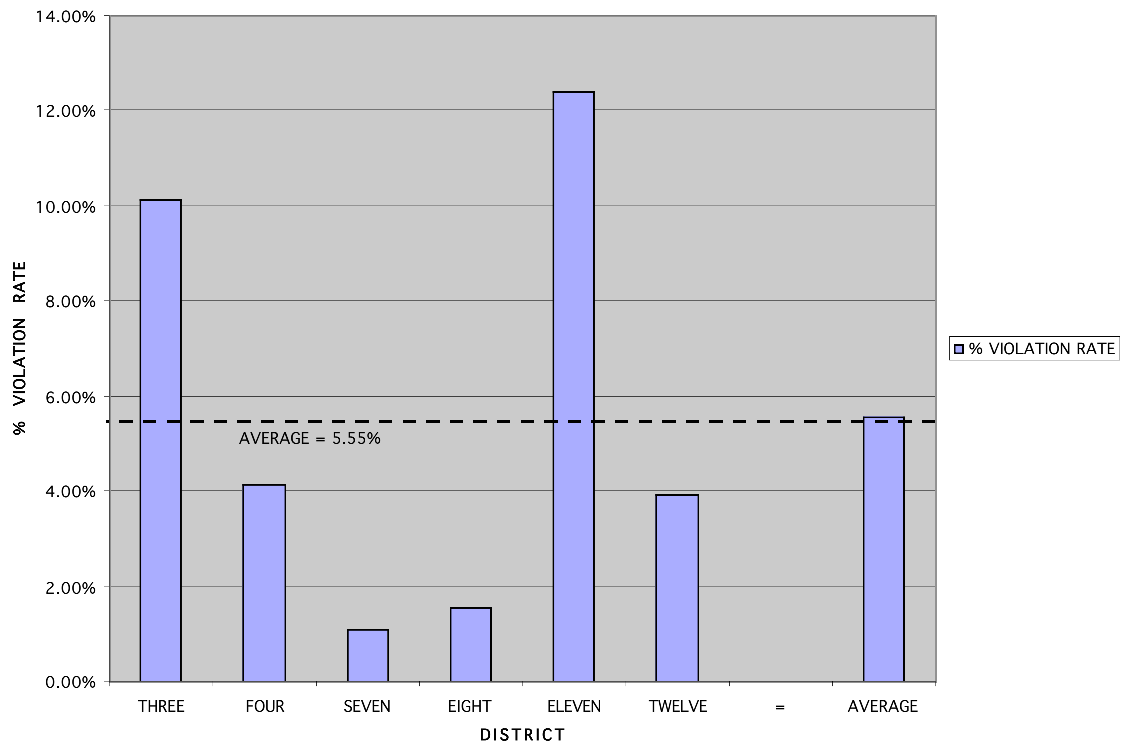


Figure 7.8 Violation Rates Per District

The average violation rate across all districts was 5.6%, well below the 10% rate identified in past studies (for example, Billheimer, 1990) as a threshold for concern. However, violation rates varied markedly from District to District, and the rates in Districts Three and Eleven both exceeded this threshold. The violation rates measured on District Eleven freeways generally exceed those measured in other Districts by a considerable margin. Local CALTRANS personnel speculated that the high rates might be traced to a lack of steady enforcement by the CHP.

Violation rates were not always abnormally high in District Eleven. Early observations made on I-15 shortly after the opening of the reversible lanes recorded rates ranging between 2% and 6%. It is possible that the introduction of FasTrak operations on the reversible lanes brought on an increased level of violations. Observers can no longer identify violators simply by counting vehicle occupants—Single Occupant Vehicles may qualify if their FasTrak pass is operating. Hence observers must count vehicle occupants and watch the FasTrak indicator at the facility entrance in order to identify violations.

Congestion Patterns. A comparison of congestion patterns in CALTRANS District Four with those in Southern California, where HOV lanes operate 24 hours per day, seven days a week, shows that the peak operating hours in Southern California counties typically last longer than the peaks on District

Four freeways. Figure 7.9 compares the peak directional flow patterns on four Northern and Southern California freeways with operating HOV lanes.

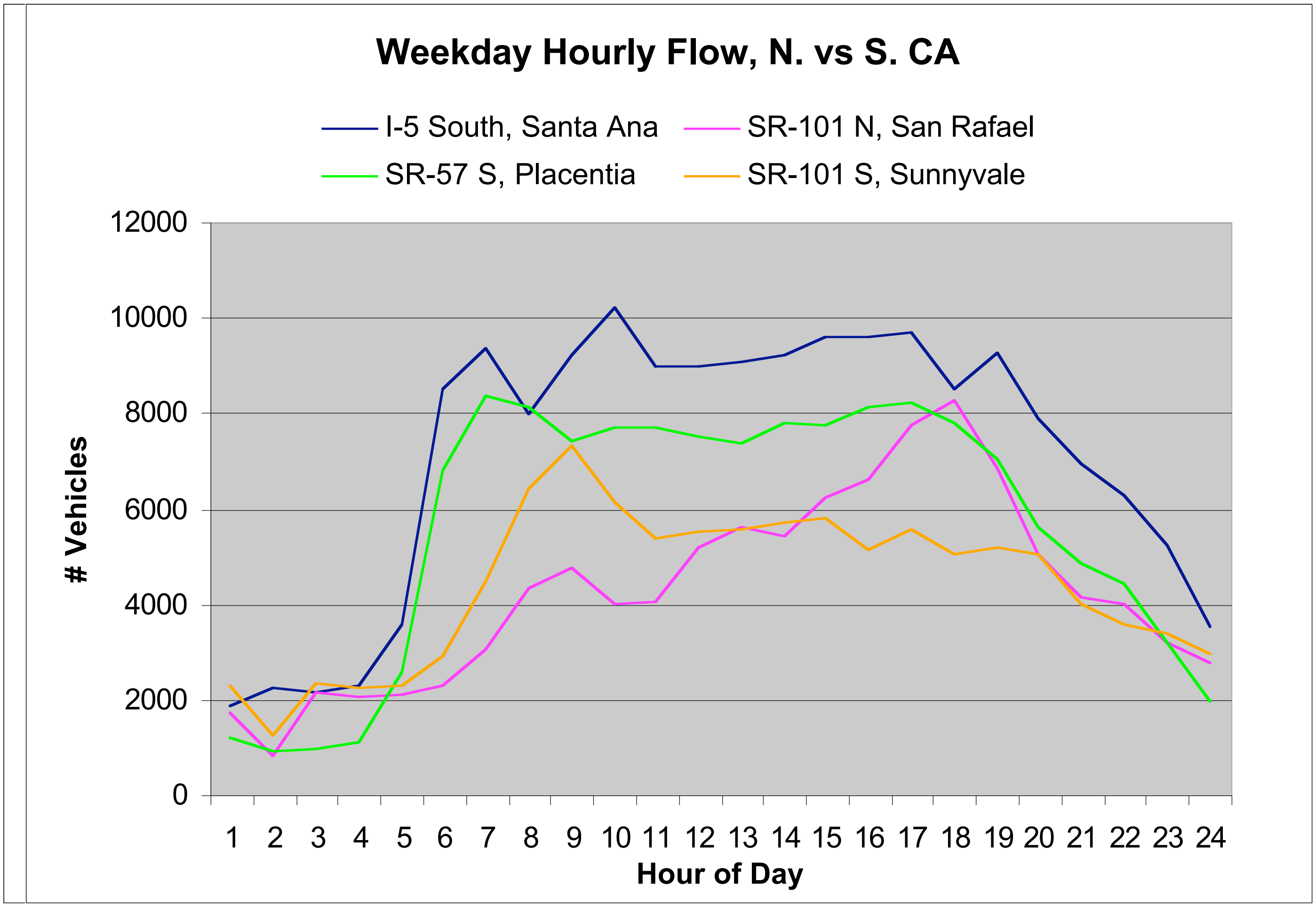


Figure 7.9 Comparison Of Congestion Patterns In Northern And Southern California

Figure 7.9 shows that the two District Four freeways, Marin-101 in San Rafael and Santa Clara-101 in Sunnyvale experience pronounced peaks in the AM and PM, respectively, while the two Southern California freeways, I-5 in Santa Ana and SR-57 in Placentia show equally heavy volumes during both morning and evening peaks, and no let-up during the middle of the day. In every case, the Southern California freeways peak earlier and the peaks last longer than those observed on Northern California freeways.

The wide and spreading peak congestion periods during the weekdays in Southern California counties, compared with the pronounced peaks on District Four freeways, helps to explain the differing CALTRANS policies of 24/7 HOV operations in Southern California and peak-hour operations in Northern California.

7.2.3 Public Opinion

Driver attitudes, perceptions, and opinions provide an important prism for viewing and evaluating high-occupancy vehicle lanes. Public attitudes toward HOV lanes in California have undergone a remarkable change, from heated opposition to HOV lanes in the wake of the disastrous experiment on the Santa Monica Freeway to wide-ranging support of the current state-wide network

It is instructive to trace the attitudes of California drivers toward HOV lanes as revealed in focus groups and surveys conducted over the period of thirty years since preferential lanes were first introduced on the Santa Monica Freeway in Los Angeles. Driver surveys were conducted for a variety of purposes over this period (See Figure 7.10), but the different surveys had enough in common to provide a glimpse of driver attitudes toward such issues as perceived time savings, carpool formation, violation rates, and general support for the HOV concept

YEAR	REPORT	SPONSOR	FIRM	SURVEY TYPE	TARGET
1975	San Bernardino Busway Evaluation	CALTRANS	Crain	Rider Survey, Telephone	CP+Solo
1976	Santa Monica Diamond Lane Evaluation	DOT	SYSTAN	Mailback	CP+Solo
1981	TSM Project Violation Rates	CHP, CALTRANS	SYSTAN	Focus Groups, Mailback	CP+Solo
1988	Route 55 Commuter Study	OCTA	OCTA	Mailback	CP+Solo
1990	HOV Lane Violation Rates	CALTRANS	SYSTAN	Focus Groups, Mailback	CP+Solo
1990	SF Bay Area HOV Lane User Study	MTC	SYSTAN	Telephone	CP
1995	O/D Studies in Eight Bay Area Corrido	CALTRANS	SYSTAN	Focus Groups, Mailback	CP+Solo
1997	O/D Studies on Three Bay Area Bridge	CALTRANS	SYSTAN	Focus Groups, Mailback	CP+Solo
1997	O/D Studies in Six Bay Area Corridors	CALTRANS	SYSTAN	Focus Groups, Mailback	CP+Solo
2002	HOV Lane Performance Evaluation	LACMTA	PB Group	Telephone, Mailback	CP+Solo
2002	2002 HOV Lane Master Plan Update	MTC, CALTRANS	DKS	Web Site, Mailback	CP+Solo
2003	Orange County Driver Survey	SCAG	SYSTAN	Focus Groups, Mailback	CP+Solo

Figure 7.10 Chronological List Of HOV Lane Surveys In California

HOV Lane Support . Support for HOV lanes in California has grown markedly over time, from opposition to a few early projects to wide-ranging support from both carpoolers and solo drivers. Figure 7.11 summarizes this growth in both Northern and Southern California. In Northern California, support has grown from 31% for the ill-fated Alameda 580 experiment to an areawide response of 60% support (85% from carpoolers and 50% from non-carpoolers) in 2002. In Southern California, the growth is even more impressive, from 14% in the wake of the Santa Monica Diamond Lanes to 75% in a recent Orange County survey. Drivers responding to the 2003 SCAG survey of Orange County drivers showed strong support for carpool lanes, with 75.8% of all drivers expressing either support (32.7%) or strong support (43.1%) and only 11.7% expressing opposition. The remaining 12.6% of respondents were neutral

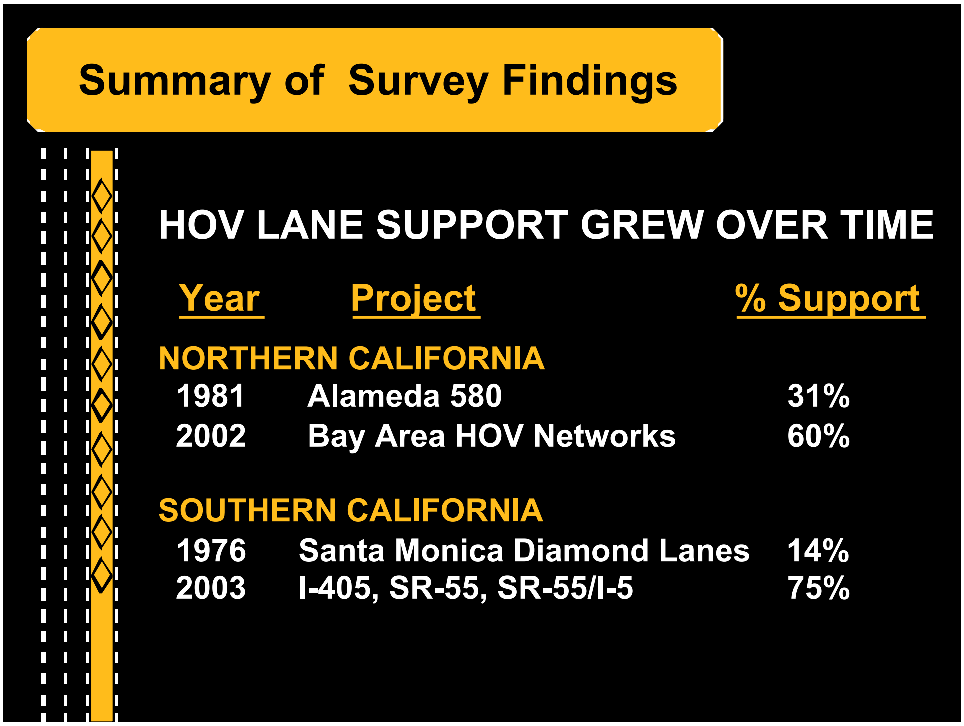


Figure 7.11 Growth In Carpool Lane Support

Perceived And Actual Time Savings . A common thread in all survey results, from the earliest to the most recent, is the agreement that HOV lanes save time for carpoolers and the tendency of both carpoolers and non-carpoolers to overestimate that savings. These findings were confirmed in the 2003 SCAG survey, which showed that both carpoolers and solo drivers tended to overestimate the amount of time they could save by using the bus/carpool lanes along their morning route. The average HOV lane savings estimated by carpoolers and solo drivers on the three routes covered by the survey are plotted in Figure 7.12 and compared with the most recent estimates of time savings measured by speed runs or SCAG's PeMS data base. The tendency of drivers to overestimate the amount of time to be saved by using HOV lanes is an added plus for the lane's ability to attract ride sharers.

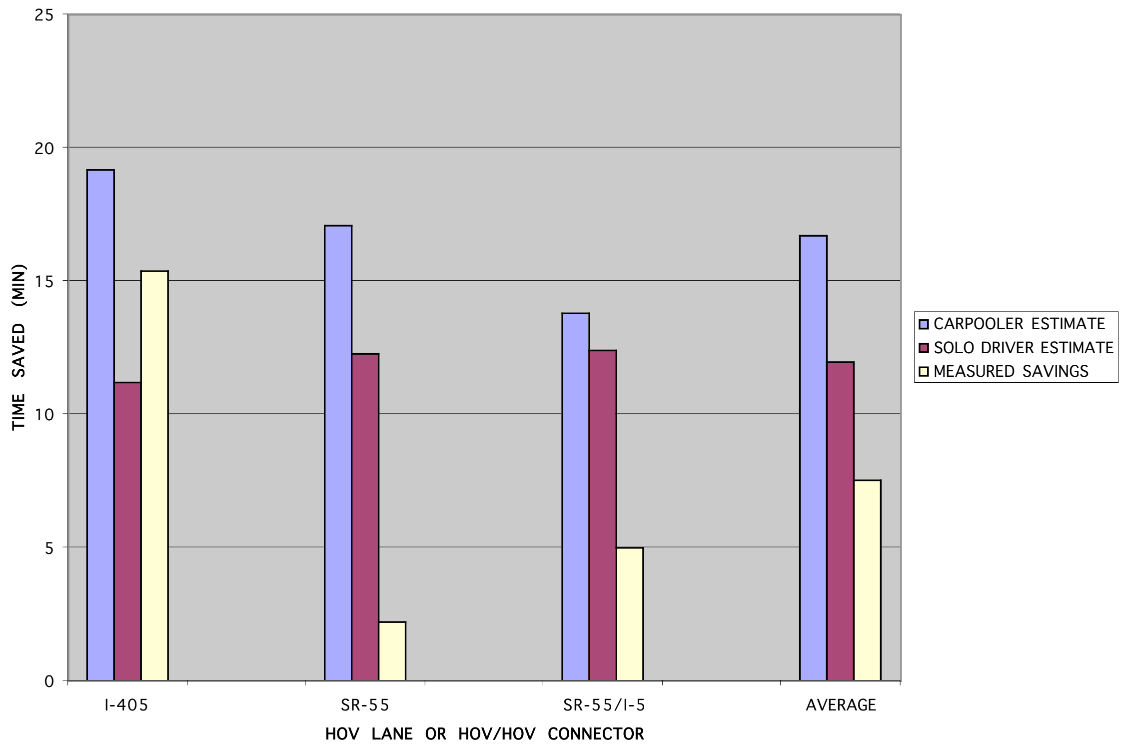


Figure 7.12 Estimated And Actual HOV Lane Time Savings

Carpool Composition. Another finding common to all of the surveys conducted among both Northern and Southern California ride-sharers involves the formation and composition of carpools. The vast majority of carpools are formed either with family members or co-workers. In the 2003 survey conducted by SCAG, an estimated 90% of all carpool lane users reported that they had formed their carpools either with family members (54%) or co-workers (36%). Only 3.3% of all carpoolers surveyed said that company carpool programs had helped with the formation of their carpool, while only 2.2% cited ride matching services.

Carpool Longevity. One of the less-well-known but most important effects of carpool lanes is their impact on carpool longevity. A recent survey of Southern California drivers suggests that the life span of carpools nearly doubled in certain corridors in the years after HOV lanes were introduced. While Northern California lacks the pre-HOV-lane surveys needed to make this before/after comparison, a series of recent surveys suggest that a similar phenomenon exists in Northern California as well. In these surveys, drivers using routes with HOV lanes reported longer-running carpools than drivers in routes with no HOV lanes, and carpool longevity seemed to correspond with HOV lane longevity.

Self-Reported Impacts Of HOV Lanes. In the series of surveys undertaken over the last ten years in both Northern and Southern California, drivers using corridors with HOV lanes were asked whether the bus/carpool lanes in their corridor had caused them to change their driving patterns in any way. In Northern California, 18% of the solo drivers and 52% of the current carpoolers responding said that the HOV lanes in their corridor had caused them to change their driving patterns. The predominant change reported by solo drivers was "I changed the time I drove" (reported by 11% of respondents), while the predominant change reported by carpoolers was "I formed a regular carpool" (reported by 22% of responding ride sharers). In general, the longer an HOV lane had been in operation, the more likely it was to induce reported changes.

Changes reported by Southern California drivers paralleled those found in Northern California and are plotted in Figure 7.13.

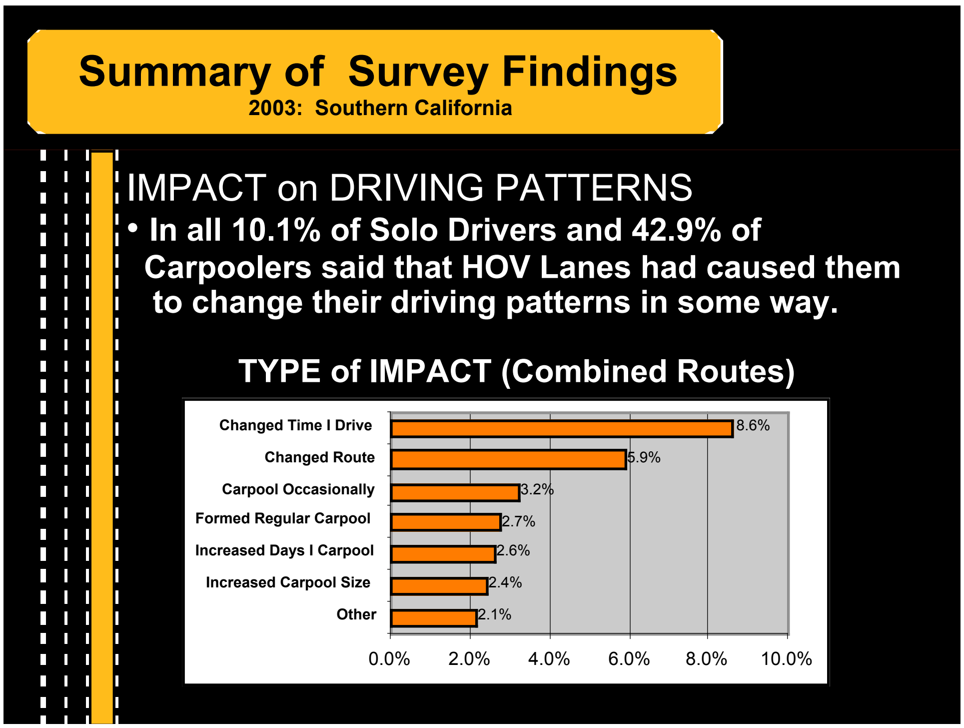


Figure 7.13 Self-Reported Impact Of HOV Lanes On Driving Patterns (Orange County, 2003)

7.2.4 Key Findings

- **Strong Support**. The general public understands and strongly supports HOV lanes. Support is strongest among carpoolers, but the majority of non-carpoolers also express support for the HOV network.

- **Good Utilization.** California's HOV lanes offer significant time savings to ride sharers and are well utilized during the peak periods.

- **Steady Growth.** It takes time for carpoolers to make and maintain ridesharing commitments. But in most cases on California's freeways, the introduction of HOV lanes has been followed by a gradual build-up of ridesharing and an increase in the life span of carpooling and vanpooling arrangements.

- **Carpool Composition.** Most carpoolers (roughly ninety percent) ride with family members or coworkers. While regular carpooling arrangements are most common, at any given time, as many as 20% of the people in carpool lanes are infrequent users who share rides roughly once every other month. Relatively few (less than five percent) ride sharers report that their carpools were formed through employer or rideshare matching services.

- **Time Savings.** Except in a few instances where the HOV lanes themselves are congested, HOV lanes provide time savings ranging from one minute to sixteen minutes per trip.

- **Safety.** There is not enough evidence to state whether HOV lanes increase or decrease accidents when installed on mainline freeways. However, the installation of direct HOV-to-HOV connectors has almost universally reduced accident rates in the vicinity of the affected intersections

- **Violation Rates.** Although violation rates exceed the ten percent level identified as a threshold for concern in Districts Three and Eleven, they are well below five percent in other CALTRANS Districts.

- **Sources of Increased Carpooling.** For the most part, there is no way of knowing whether the measured increases in carpooling following the introduction of mainline HOV lanes came from newly formed carpools or existing carpools which changed routes to take advantage of improved travel times. As time goes on, the question of whether the carpools added to the freeway mix following were new or diverted becomes less and less important. If new, they represented an immediate improvement in the overall vehicle occupancy picture. If diverted, they filled space reserved to reward ridesharing behavior and freed up the space they left to relieve the congestion faced by non-carpoolers. Over time, there is evidence that the HOV lanes cause carpools to last longer, regardless of how they came to be in the lanes.

7.3 ASSESSING, DEVELOPING, AND DEMONSTRATING METHODS FOR MODELING AIR QUALITY

The current investigation modified the previous FREQ air quality model, which was formulated in 1991, to represent the most up-to-date and comprehensive methodology for predicting air quality. The updated methodology was developed, tested, and demonstrated in a FREQ analysis and as an off-line module in conjunction with the PeMS (Performance Measurement System) developed jointly by Caltrans, the University of California at Berkeley, and the Partnership for Advanced Technology on the Highways (PATH).

7.3.1 Model Development

The project team modeled emission rates for three pollutants, hydrocarbons (HC), carbon monoxide (CO), and carbon monoxide (NOx) as a function of traffic intensity and speed, vehicle fleet year, ambient temperature, and vehicle classification. Updated rate tables were developed by incorporating the latest data from the California Air Resources Board's EMFAC (EMission FACtors) model, EMFAC2002, in the most recent version of the FREQ model. Since both EMFAC2002 and FREQ are macroscopic models keyed to average trip speeds, the two models proved quite compatible.

The chief difficulty in incorporating EMFAC2002 data into the FREQ format was in translating the thirteen vehicle categories used by EMFAC2002 into the three vehicle categories (autos, gas trucks, and diesel trucks) recognized by FREQ. Once this was accomplished, the model updating was fairly straightforward and entailed the development of tables relating vehicle speeds in five mph increments to the emission rates in grams per mile for each of the three pollutants. A sample rate table appears below in Figure 7.14.

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2005 Annual - 65 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant: 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
Total Hydrocarbons															
Autos	1.866	1.282	0.924	0.700	0.556	0.462	0.403	0.368	0.352	0.353	0.371	0.410	0.475	0.491	0.155
Gas trucks	3.530	2.377	1.675	1.236	0.954	0.770	0.651	0.575	0.532	0.515	0.523	0.555	0.619	0.631	0.294
Diesel trucks	2.558	2.008	1.612	1.322	1.109	0.951	0.833	0.747	0.683	0.639	0.612	0.599	0.599	0.612	0.213
Carbon Monoxide															
Autos	9.726	8.125	6.975	6.123	5.483	4.999	4.639	4.386	4.233	4.185	4.264	4.509	4.999	5.211	0.811
Gas trucks	17.996	13.462	10.593	8.712	7.446	6.586	6.015	5.667	5.514	5.557	5.825	6.386	7.371	8.037	1.500
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809
Oxides of Nitrogen															
Autos	0.900	0.778	0.688	0.624	0.579	0.548	0.529	0.520	0.521	0.533	0.554	0.588	0.638	0.643	0.075
Gas trucks	1.769	1.601	1.487	1.411	1.363	1.339	1.333	1.342	1.367	1.407	1.462	1.537	1.635	1.657	0.147
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Figure 7.14 Sample Freq Emission Rate Factors Table For Total Hydrocarbons, Carbon Monoxide, And Oxides Of Nitrogen

In all, forty-two tables of the type shown in Figure 7.14 were developed, reflecting seven operating years (1990, 1995, 2000, 2005, 2010, 2015, and 2020) and six ambient temperatures (55, 65, 75, 85, 90, and 105 degrees Fahrenheit).

7.3.2 Model Testing And Demonstration

The updated model was tested and demonstrated as part of Task 4 of the current study in the FREQ modeling of two sections of the California freeway system: I-580 in Northern California and I-210 in Southern California (See Section 7.4 of the Conclusions). In Task 5, the model was also incorporated into an off-line module for use with the PeMS routines for gathering, processing, and analyzing real-time data on California freeways.

A conceptual view of the off-line methodology appears in Figure 7.15. This figure outlines the basic PeMS processing steps, along with the calculation of emission rates at specific loop detectors and the aggregation of rates across all lanes of traffic to produce emission estimates for the freeway segment covered by the loop detectors. Rates were calculated and aggregated at five minute increments.

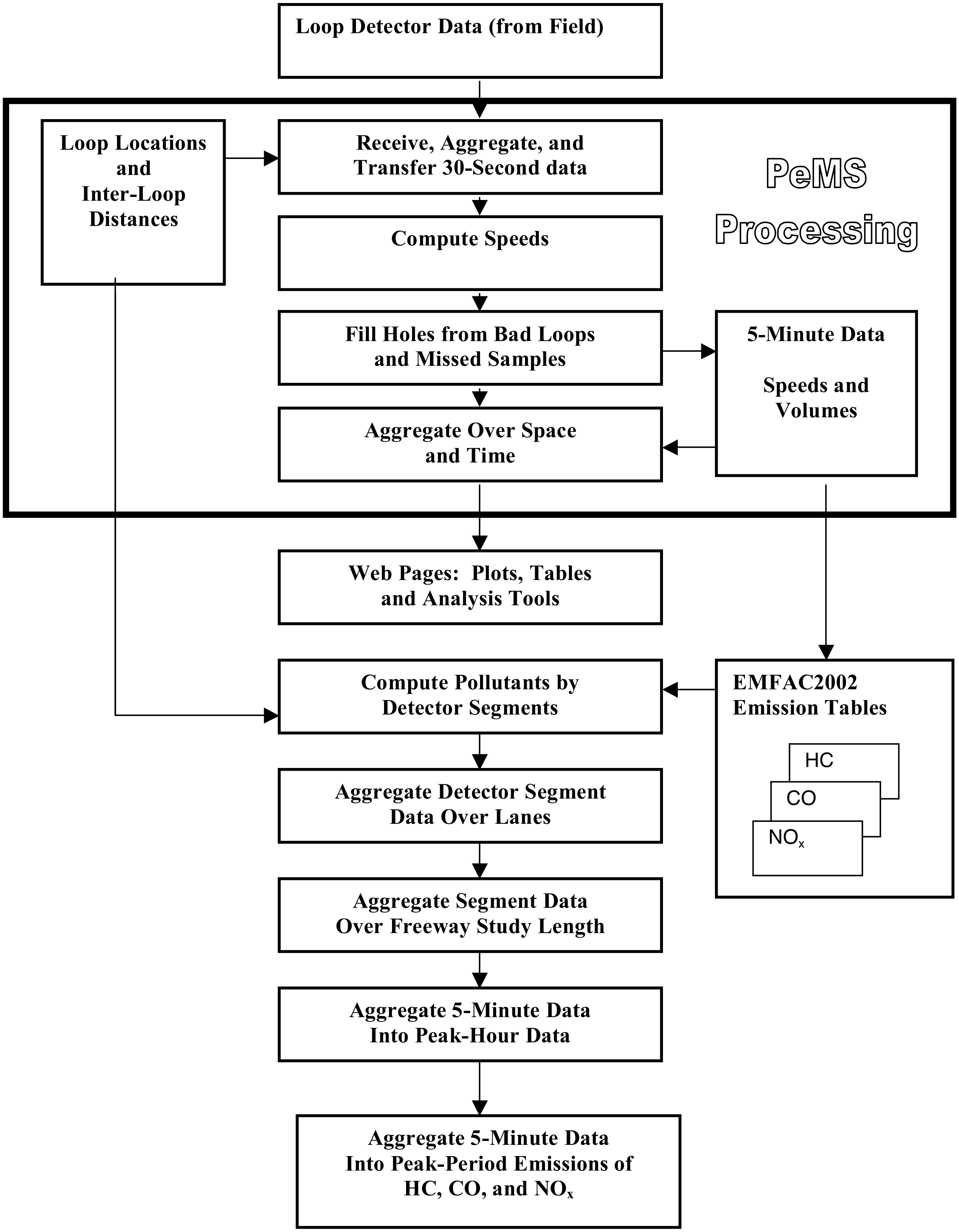


Figure 7.15 Overview of Computation Process

The off-line methodology was demonstrated along a 14.1 mile section of I-210 in Los Angeles, the same stretch of freeway modeled by FREQ in Task 4. The project team computed the emissions produced in five-minute increments for the westbound traffic recorded by loop detectors at each of the twenty-two detector stations along the length of the study section on April 10, 2006. Emissions at the twenty-two detector stations were then aggregated for the peak morning hour, the peak morning period, and the entire day.

Total emissions for the peak morning period (6:00 am to 10:00 am) on April 10, 2006 are shown below in Figure 7.16. On a per-vehicle-mile basis, HO and CO emission rates were slightly higher in the HOV lane (8.5% and 7.4%, respectively), while NOx emission rates were 6.4% higher in the mainline lanes.

PEAK PERIOD EMISSIONS (GRAMS)				
LOCATION:	I-210 W	MP 39.5	TO	MP 25.4
DATE:	4/10/06			
	VEH-MI	**HYDRO-CARBONS**	**CARBON MONOXIDE**	**OXIDES OF NITROGEN**
MAINLINE LANES	413912	162687	1748490	475834
PER VEH MILE		0.386	4.203	1.168
HOV LANE	62538	26169	282150	68343
PER VEH MILE		0.418	4.512	1.093
TOTAL FREEWAY	476450	188856	2030641	544177
PER VEH MILE		0.396	4.262	1.142

Figure 7.16 Peak-Period Emissions On Westbound I-210 (April 10, 2006)

As the methodology was being demonstrated, the project team wondered whether speed tables reflecting 1- mph increments might represent a significant improvement in particle estimation. To explore this possibility, the team developed computerized tables relating particle emissions of HC, CO, and NOx to vehicle speeds in 1-mph increments between 5-mph and 80mph, along with a routine to interpolate emission rates at 1-mph increments. These denser particle curves were applied to one of the locations along the I-210 W study section.

Examination of each of the 5-minute data intervals over the 24-hour period on April 10 showed that particle estimates made using 5-mph increments were consistently higher or equal to the estimates made using 1-mph increments, reflecting the concave nature of the curves themselves. Differences for the 5-minute intervals never exceeded 0.94%, and averaged 0.41% for HC, 0.34% for CO, and

0.41% for NOx. These differences were judged to be small enough to justify the continued use of 5-mph increments in calculating emissions using the FREQ program. However, the developed off-line methodology is capable of accommodating either 1-mph or 5-mph increments.

7.4 FREQ ANALYTIC FINDINGS

Once the FREQ model had been modified to reflect the most up-to-date techniques for predicting air quality, the upgraded model was used to analyze design and policy options along two segments of California freeway.

1. Twenty-eight miles of the I-580 freeway in the Dublin-Livermore area of District Four, eastbound during the afternoon peak period; and
2. Fifteen miles of the I-210 freeway in the Pasadena area of District Seven, westbound during the morning peak period.

7.4.1 I-580 Analysis Results

Two alternative operating policies were modeled on the 28-mile stretch of I-580. The study segment currently has no HOV lane, although plans to install one are in the works, so that the analysis considered two alternative operating policies for adding such a lane:

1. An occupancy requirement of three or more persons (3+); and
2. An occupancy requirement of two or more persons (2+).

3+ Operating Policies Under Current Demand Levels. The addition of a 3+ lane under conditions approaching current demand levels resulted in a traffic flow of 300 to 350 vehicles per hour in the HOV lane, leaving considerable excess capacity available for future growth. Whereas congestion in the adjacent non-HOV lanes was moderate-to-heavy prior to lane construction, only minor congestion resulted when the lane was added. The addition of a 3+ lane reduced passenger-hours during the peak period by 20%, and produced modest 1% increases in total passenger miles and fuel consumption, while reducing total vehicle emissions by 1%.

3+ Operating Policies with Increased Demand Levels. When overall demand increased by 10% and the percentage of 3+ vehicles increased from 5% to 7%, HOV lane utilization increased from 300-350 vehicles per hour to 500-550 vehicles per hour, still well below the operating capacity of the lane. The level of congestion in the adjacent non-HOV lanes rose from light to moderate, causing the average speed differential between the HOV lane and the adjacent lanes to increase from 4 mph to 22 mph. The resulting increase in passenger miles was accompanied by proportional increases in total fuel consumption and vehicle emissions. However, the fuel consumption rate (measured in passenger miles per gallon) improved and the vehicle emission rate (in passenger miles per kilogram) remained unchanged.

2+ Operating Policies Under Current Demand Levels. The addition of a 2+ lane under conditions approaching current demand levels resulted in a traffic flow of 800 to 1500 vehicles per hour in the HOV lane, leaving little excess capacity for future growth. Whereas congestion in the adjacent non-HOV lanes was moderate-to-heavy prior to the HOV lane addition, no congestion occurred in the non-HOV lanes after the HOV was added. The addition of a 2+lane reduced passenger-hours during the peak period by 24% and produced a modest 1% increase in total passenger-miles. The total fuel consumption increased by 7% and the total emissions increased by 4%.

2+ Operating Policies With Increased Demand Levels. Using the FREQ model default HOV lane capacity of 1500 vehicles per hour, the HOV lane was predicted to be operating at capacity and had essential no unused capacity available for future growth.

Using the District 04 HOV lane capacity of 1650 vehicles per hour, it is estimated that a two to three percent increase in the 2+ vehicle occupancy percentage could occur before congestion in the HOV lane might occur.

It should be kept in mind that the intent of these investigations was for demonstration purposes and not implementation. If further investigations are desired, the Freeway Analysis Project staff could provide technical assistance to District 04 staff member(s).

7.4.2 I-210 Analysis Results

The analysis of operations on the 15-mile stretch of I-210 W in the Pasadena area took two forms:

1. An extensive set of sensitivity analyses were undertaken to assess the impact of a wide range of changes in traffic growth and carpooling choices: and
2. The impact of reducing the number of access points to the existing HOV lanes was analyzed.

Impact of Changes in Carpooling Percentages and Traffic Growth To assess the impact of a wide range of carpooling choices and traffic growth, the percentage of 2+ HOV vehicles was allowed to range from 4% to 36% around a baseline condition of 12%, while traffic growth factors ranged from 0.95 to 1.10 (with a baseline condition of 1.0). These changes significantly affected the performance of the HOV lanes.

- Heavy congestion occurred in the HOV lane and queues from the HOV lane backed into the non-HOV lanes when 2+ vehicle factors reached 20% under all growth conditions;

- Some congestion occurred in the HOV lane when 2+ vehicle occupancies reached 16% under all growth conditions. As a result, speeds in the HOV lane were only slightly greater than speeds in the non-HOV lanes.

The greatest "window of opportunity" for HOV lane success occurred when the 2+ HOV vehicle occupancy rates ranged from 8% to 12%. Within these parameters,

- No congestion occurred in the HOV lane;

- Speeds in the HOV lane were significantly (17 mph to 42 mph) greater than speeds in the non-HOV lanes, encouraging non-HOV drivers to consider carpooling; and

- Average fuel consumption rates and vehicle emission rates were among the best of the conditions analyzed.

When the 2+ HOV vehicle occupancy levels dropped as low as 4%, speed differentials improved and many other indicators remained positive, but flow levels in the HOV lane ranged between 100 and 500 vehicles per hour, causing concerns about the possibility of an "empty lane syndrome."

Impact of Reducing the Number of HOV Lane Access Points. Because the performance of the HOV lanes under the existing design deteriorated when the percentage of 2+ HOV-eligible vehicles approached 16%, the impact of limiting access to the HOV lane by decreasing the number of intermediate access points along the study segment was investigated.

Under conditions of reduced access, congestion did not occur in the HOV lane until the 2+ vehicle percentage reached 24%, and then only for growth factors of 1.05 or greater. For lower growth factors, congestion did not occur until the 2+ vehicle percentage reached 28%.

Although the HOV lanes were congestion-free under most of the conditions examined, congestion in the non-HOV lanes increased considerably. As a result, while speeds in the HOV lane were significantly greater than speeds in the non-HOV lanes, the reduced-access design saw an increase in total passenger hours, fuel consumption, and vehicle emission levels, and a decline in passenger-miles served over all combinations of carpool percentages and demand levels.

The bottom line was that reduction of the number of access points to the HOV lane did provide for improved operations in the HOV lane and maintained a speed differential significantly favoring the HOV lane users. However in terms of the combined performance of both the HOV lane and the non-HOV lanes, the consequences were negative.

7.4.3 Summary Of FREQ Analysis Highlights

A number of lessons were learned from these two HOV freeway investigations and highlights include the following:

- Vehicle occupancy distributions have a very significant effect on the performance of on-freeway HOV lane facilities. Accurate data on vehicle occupancy distributions is essential for the realistic modeling of such facilities.

- Traffic demand levels have a very significant effect on the performance of an on-freeway HOV lane facility. Modeling of HOV facilities should include both current and future traffic demand levels. Current comprehensive traffic counts should be accurately measured and future traffic demands predicted with care.

- The FREQ model was well suited for investigating on-freeway HOV lane facilities. The model was very flexible in modeling various combinations of HOV lane design and operational parameters and providing a wide variety of measures of performance.

- In both cases the length of the freeway study section and the duration of the peak period were not adequate, because of data limitations, to include the total impacts of the HOV lane facility. Greater attention is needed to design the modeling to completely encompass the impacts of HOV lane facilities under current and future traffic conditions.

- The design of a successful HOV lane facility is a very difficult task and requires careful analyses prior to implementation in order to move toward an optimum design. Future increases in freeway traffic demands and increases in the percent of HOV lane users due to good HOV lane operations are likely to require changes in the HOV lane design and operational parameters over time. This will require careful monitoring the operations of HOV lane facility and further modeling analyses.

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APPENDIX A

This appendix contains graphs comparing the new FREQ Emission Rate Tables which are based on data produced by the California Air Resources Board's EMFAC2002 Emissions Model to the previous FREQ Emission Rate Tables which were based on data produced by their earlier EMFAC7E Model. There were previously twelve FREQ Emissions Rate Tables, one for the years 1990, 1995, and 2010, for each of four temperatures, 55, 65, 85, and 95 degrees Fahrenheit. Although there are forty-two new FREQ Emission Rate Tables representing seven years for six temperatures, only those tables that have a corresponding table in the previous FREQ are included in these graphs.

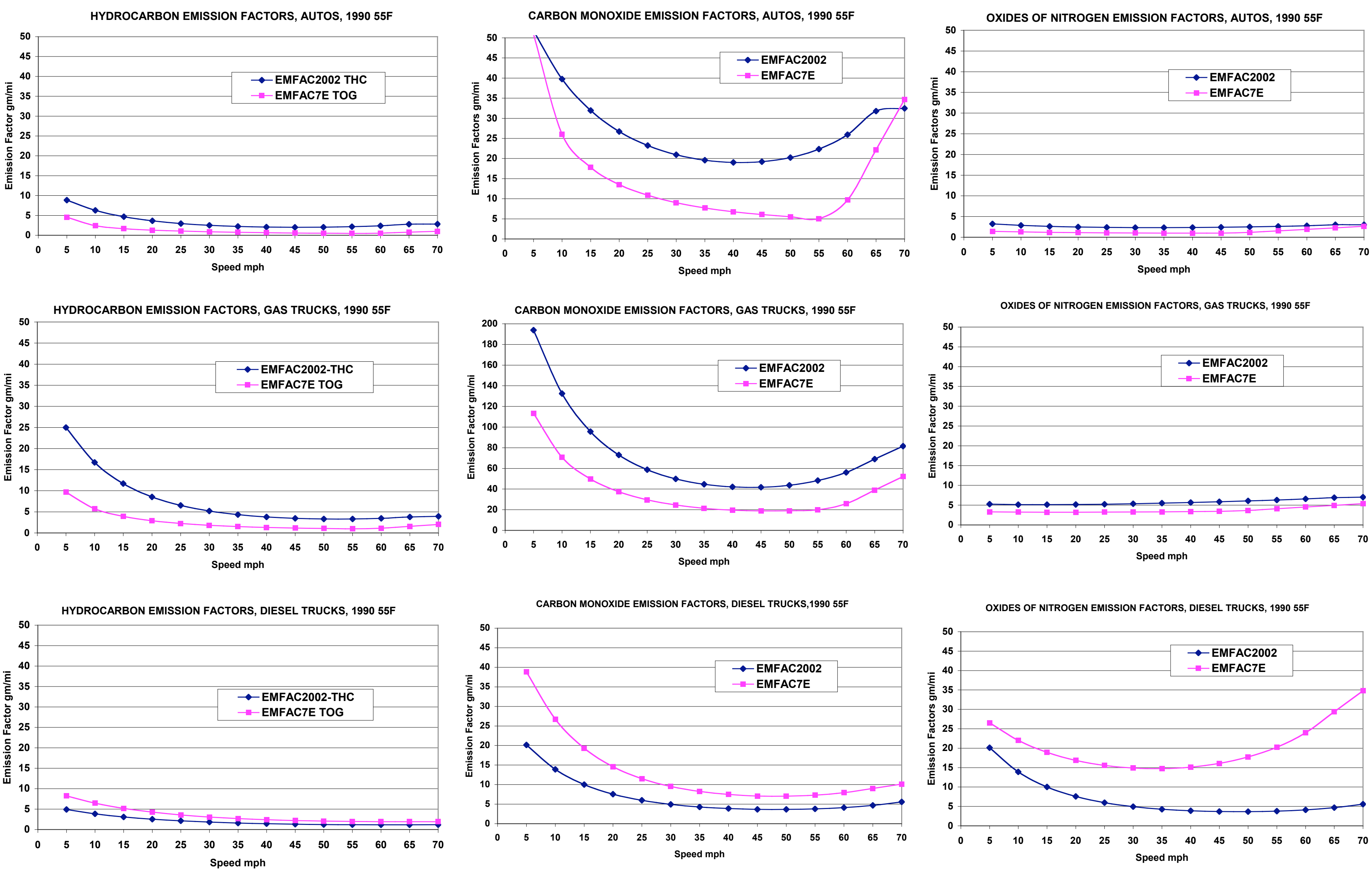

Figure A.1 Comparison of EMFAC7E and EMFAC2002 FREQ Emission Factors for 1990 and 55 Degrees Fahrenheit

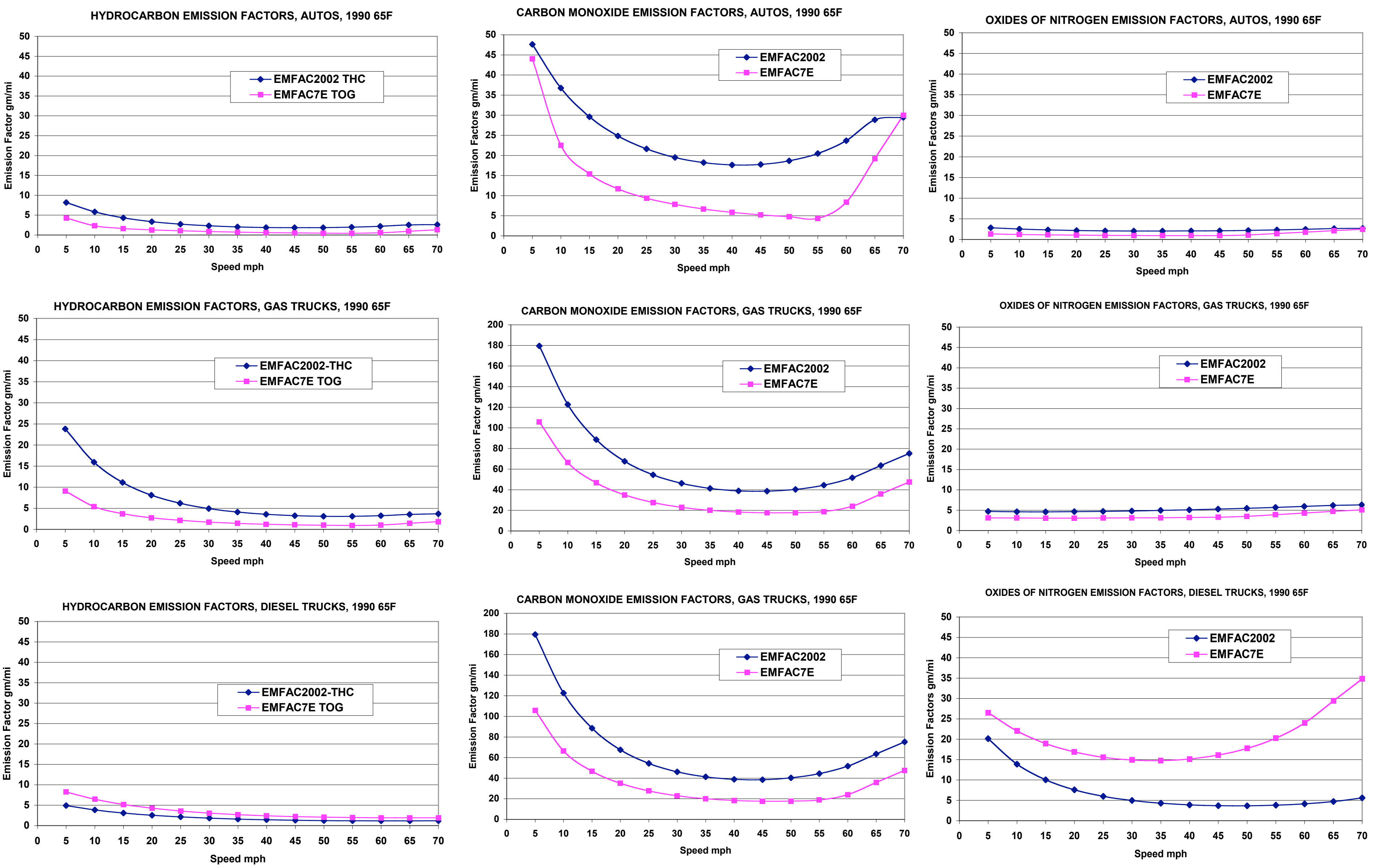

Figure A.2 Comparison of EMFAC7E and EMFAC2002 FREQ Emission Factors for 1990 and 65 Degrees Fahrenheit

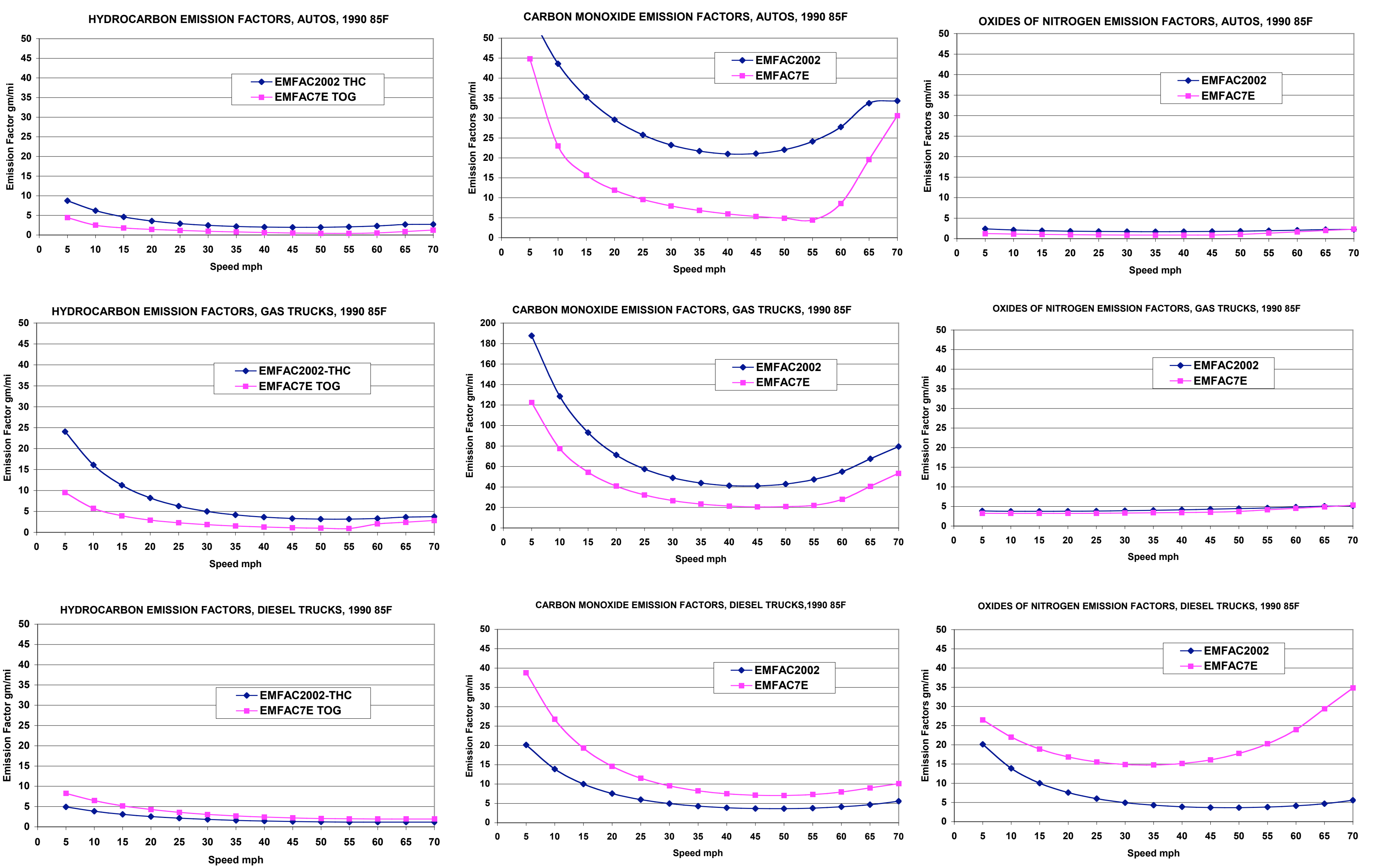

Figure A.3 Comparison of EMFAC7E and EMFAC2002 FREQ Emission Factors for 1990 and 85 Degrees Fahrenheit

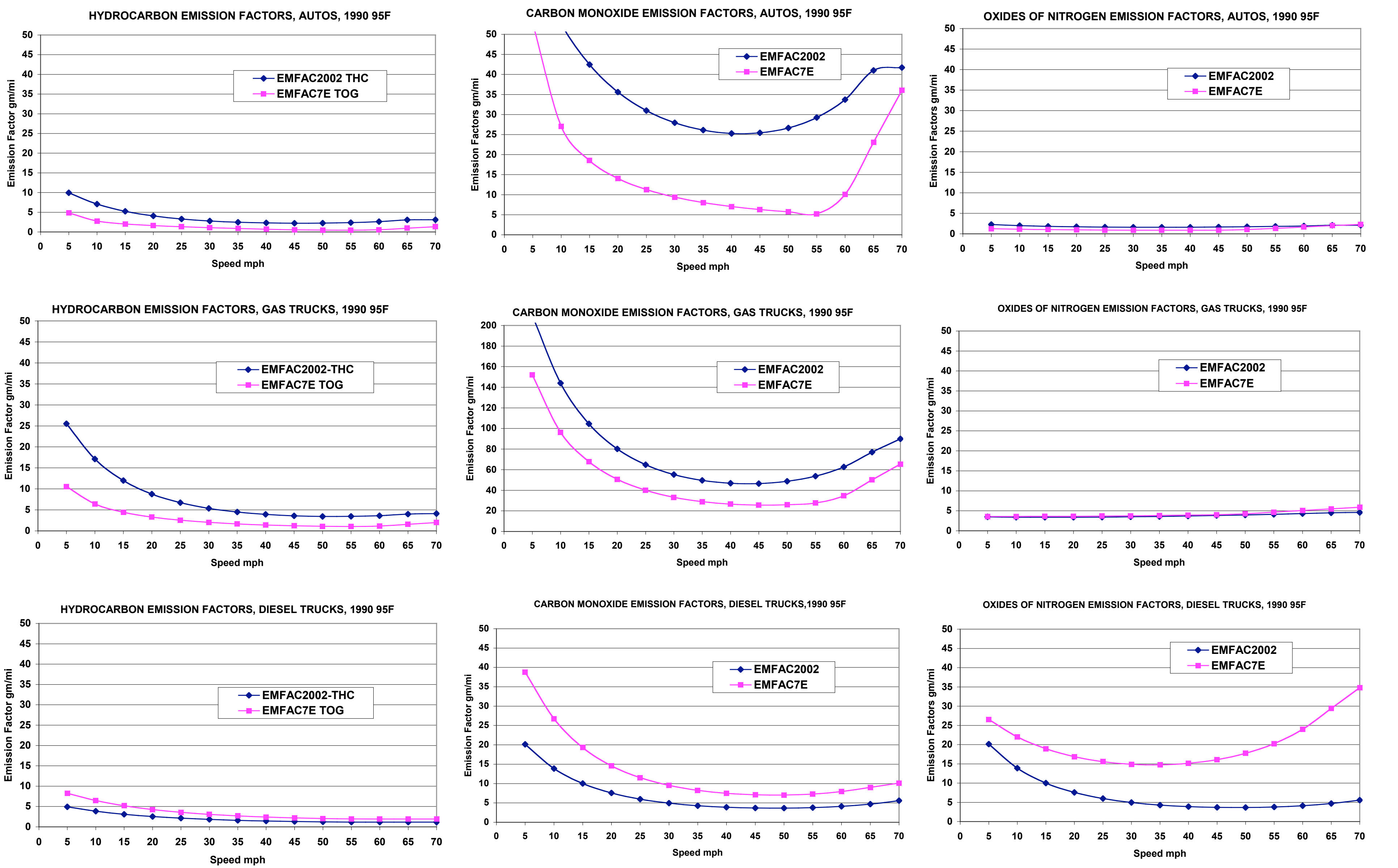

Figure A.4 Comparison of EMFAC7E and EMFAC2002 FREQ Emission Factors for 1990 and 95 Degrees Fahrenheit

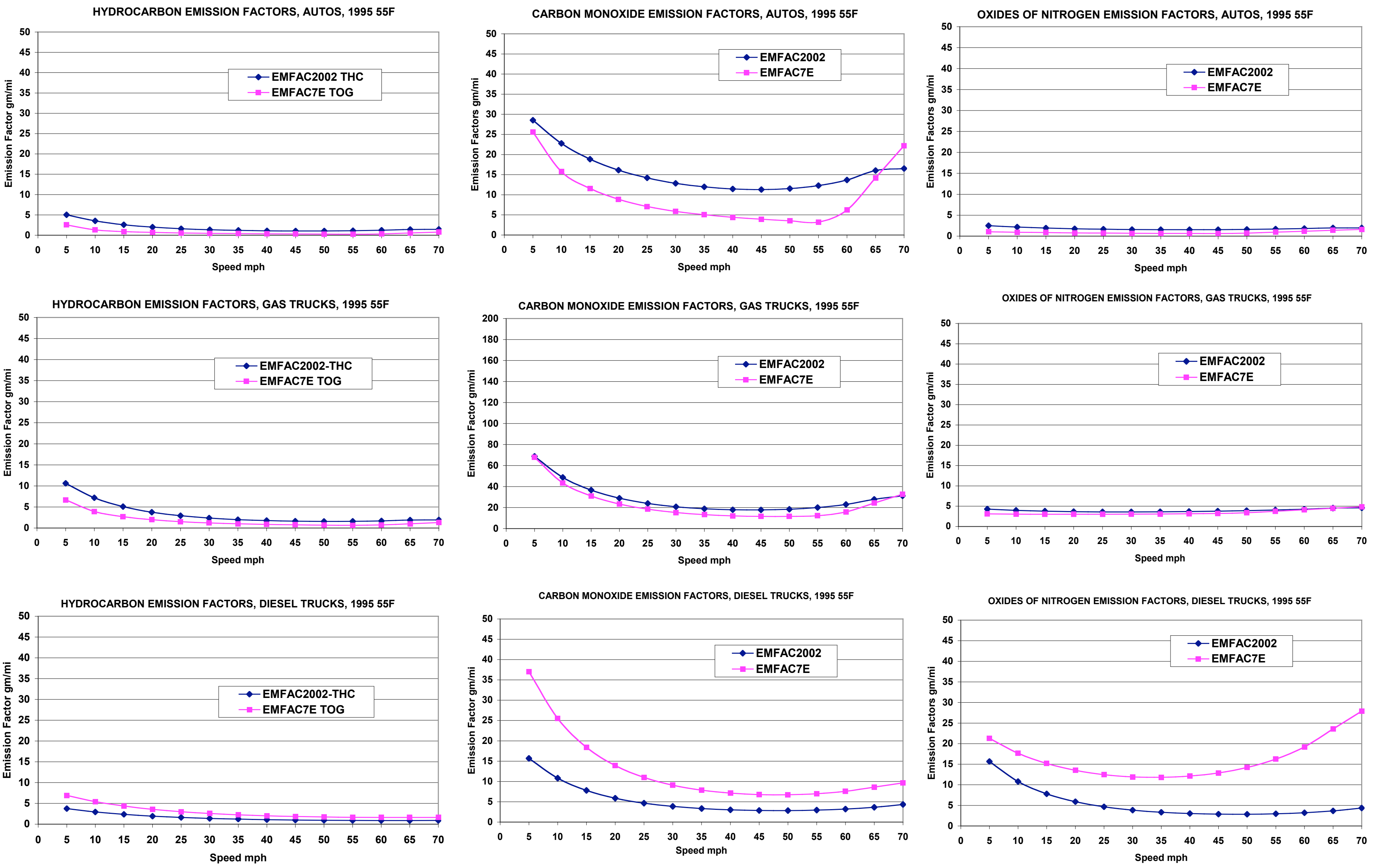

Figure A.5 Comparison of EMFAC7E and EMFAC2002 FREQ Emission Factors for 1995 and 55 Degrees Fahrenheit

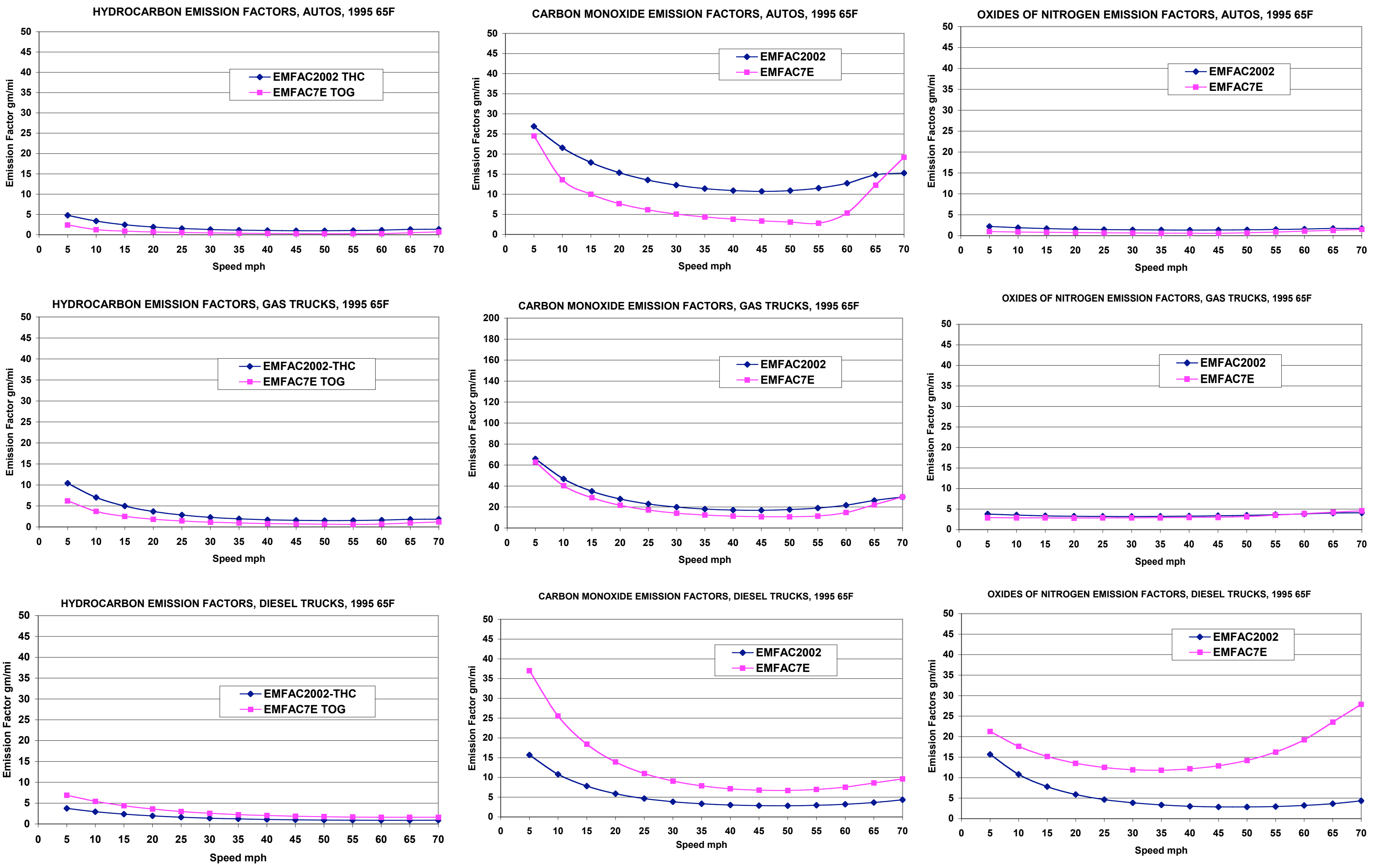

Figure A.6 Comparison of EMFAC7E and EMFAC2002 FREQ Emission Factors for 1995 and 65 Degrees Fahrenheit

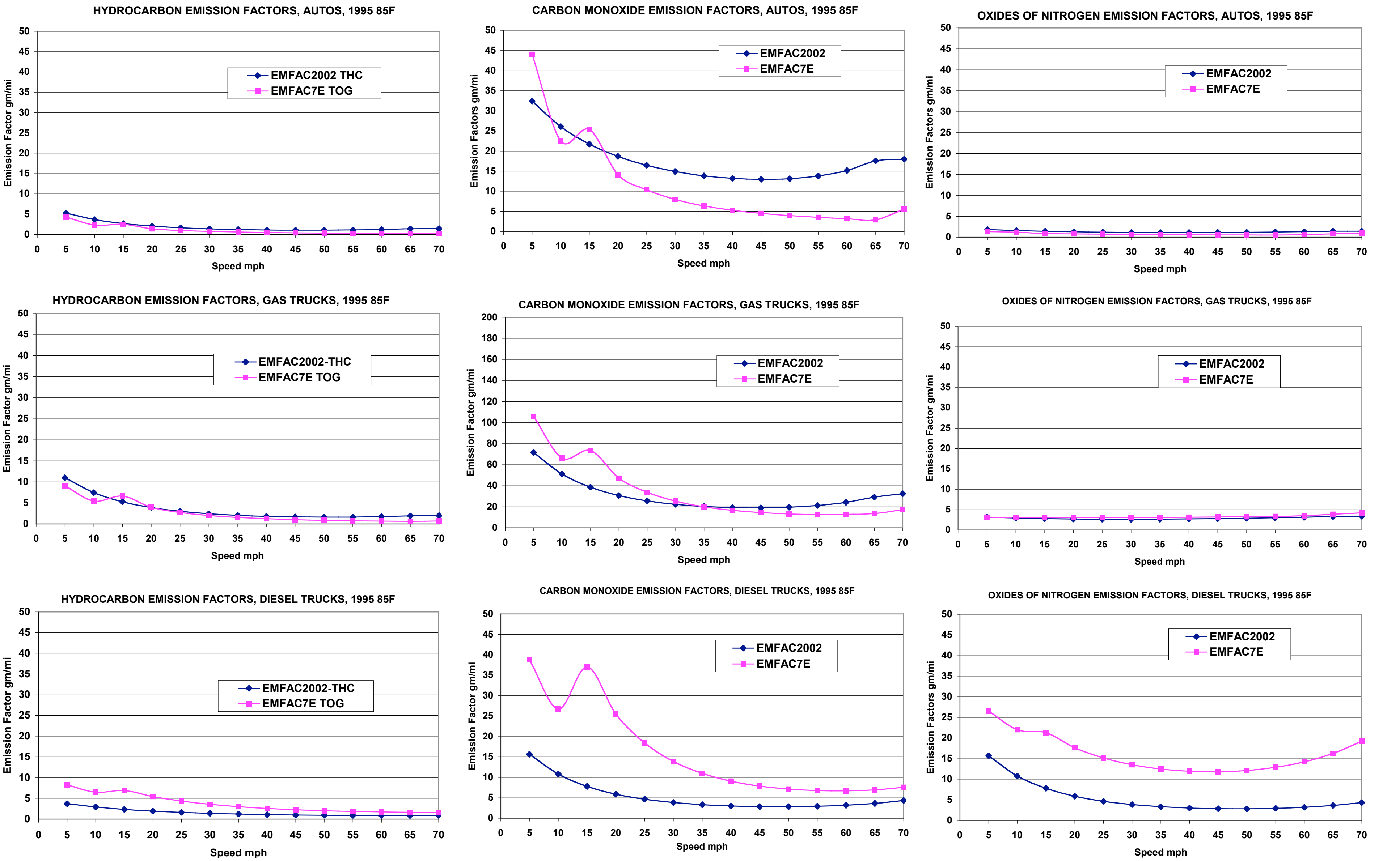

Figure A.7 Comparison of EMFAC7E and EMFAC2002 FREQ Emission Factors for 1995 and 85 Degrees Fahrenheit

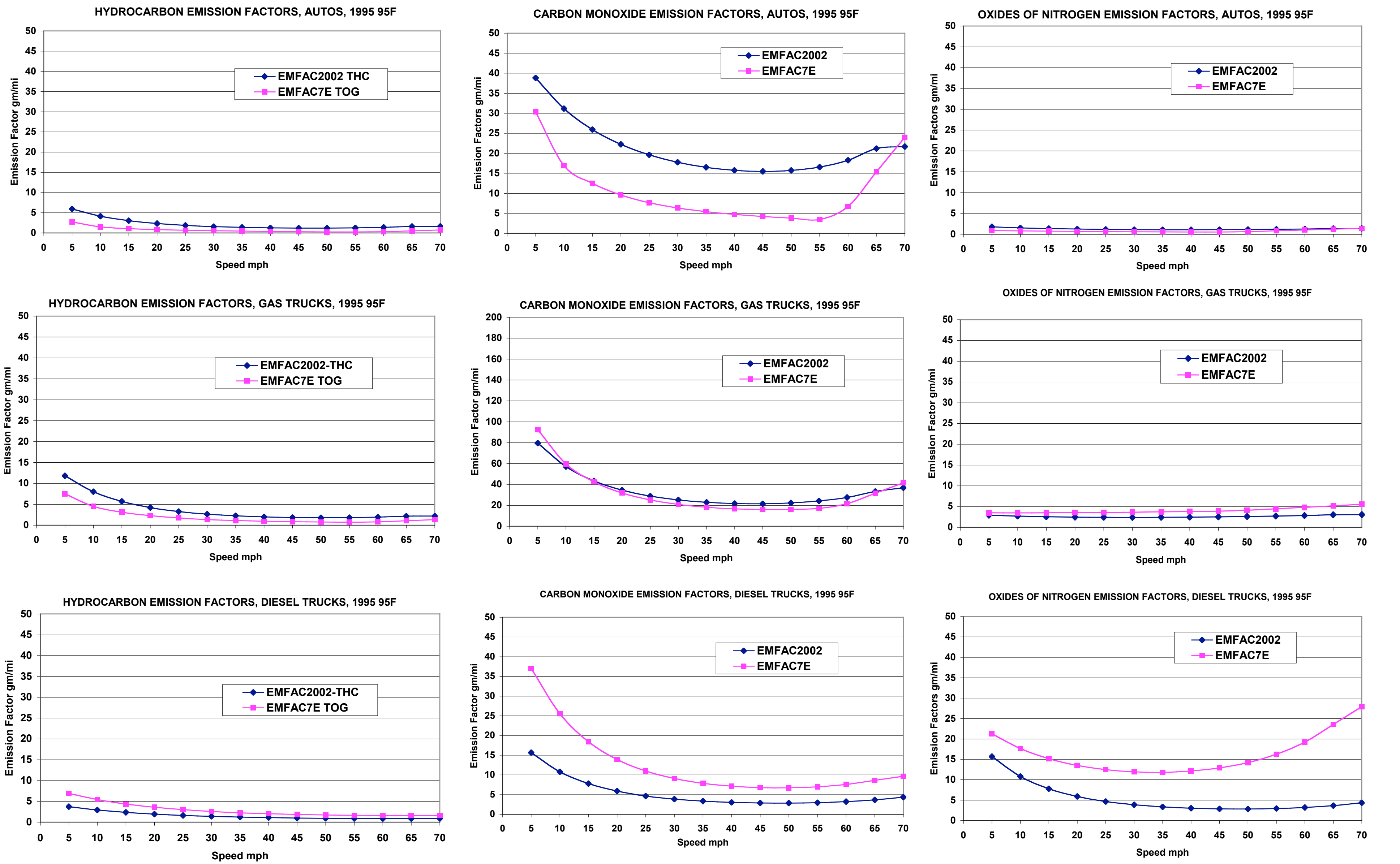

Figure A.8 Comparison of EMFAC7E and EMFAC2002 FREQ Emission Factors for 1995 and 95 Degrees Fahrenheit

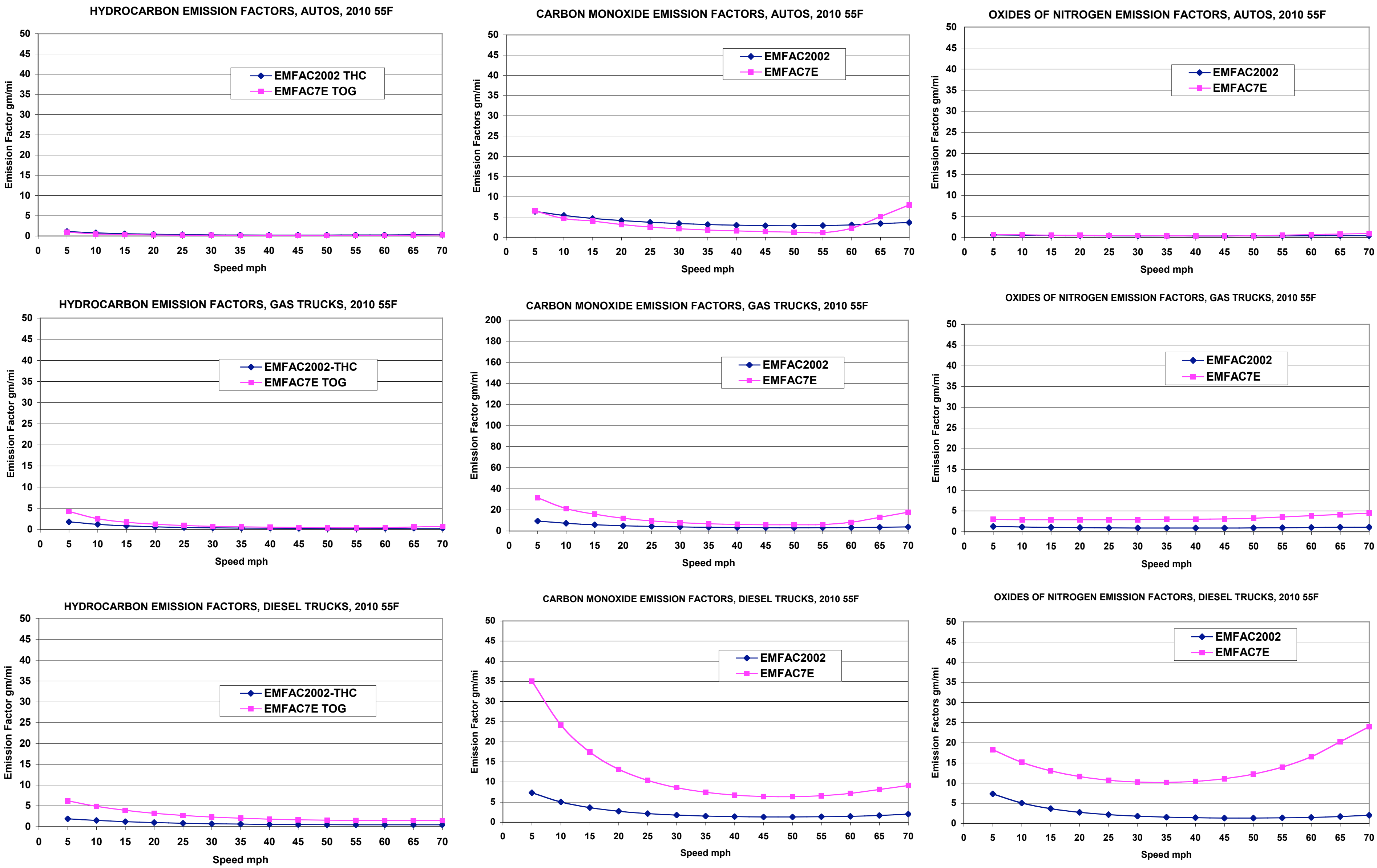

Figure A.9 Comparison of EMFAC7E and EMFAC2002 FREQ Emission Factors for 2010 and 55 Degrees Fahrenheit

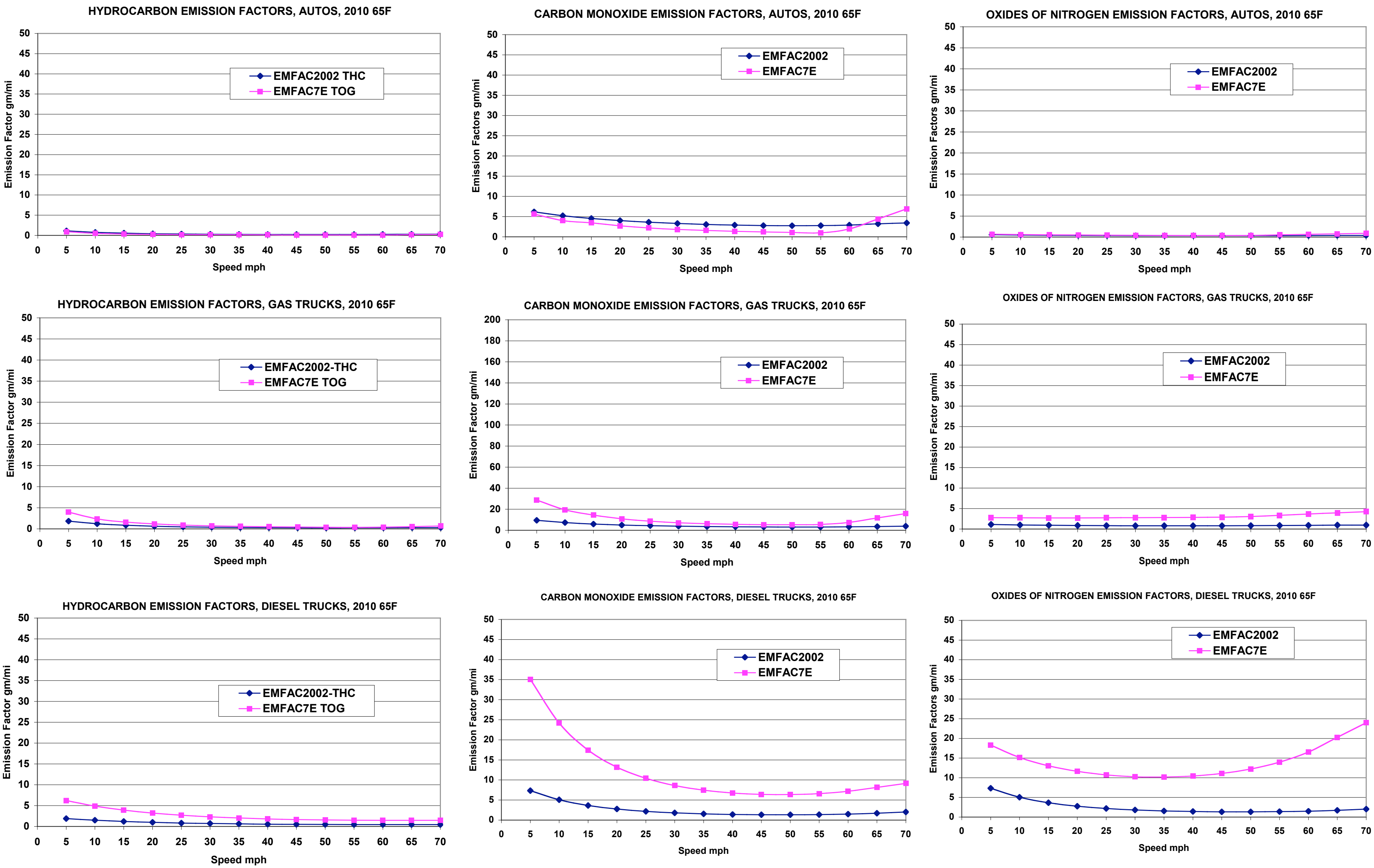

Figure A.10 Comparison of EMFAC7E and EMFAC2002 FREQ Emission Factors for 2010 and 65 Degrees Fahrenheit

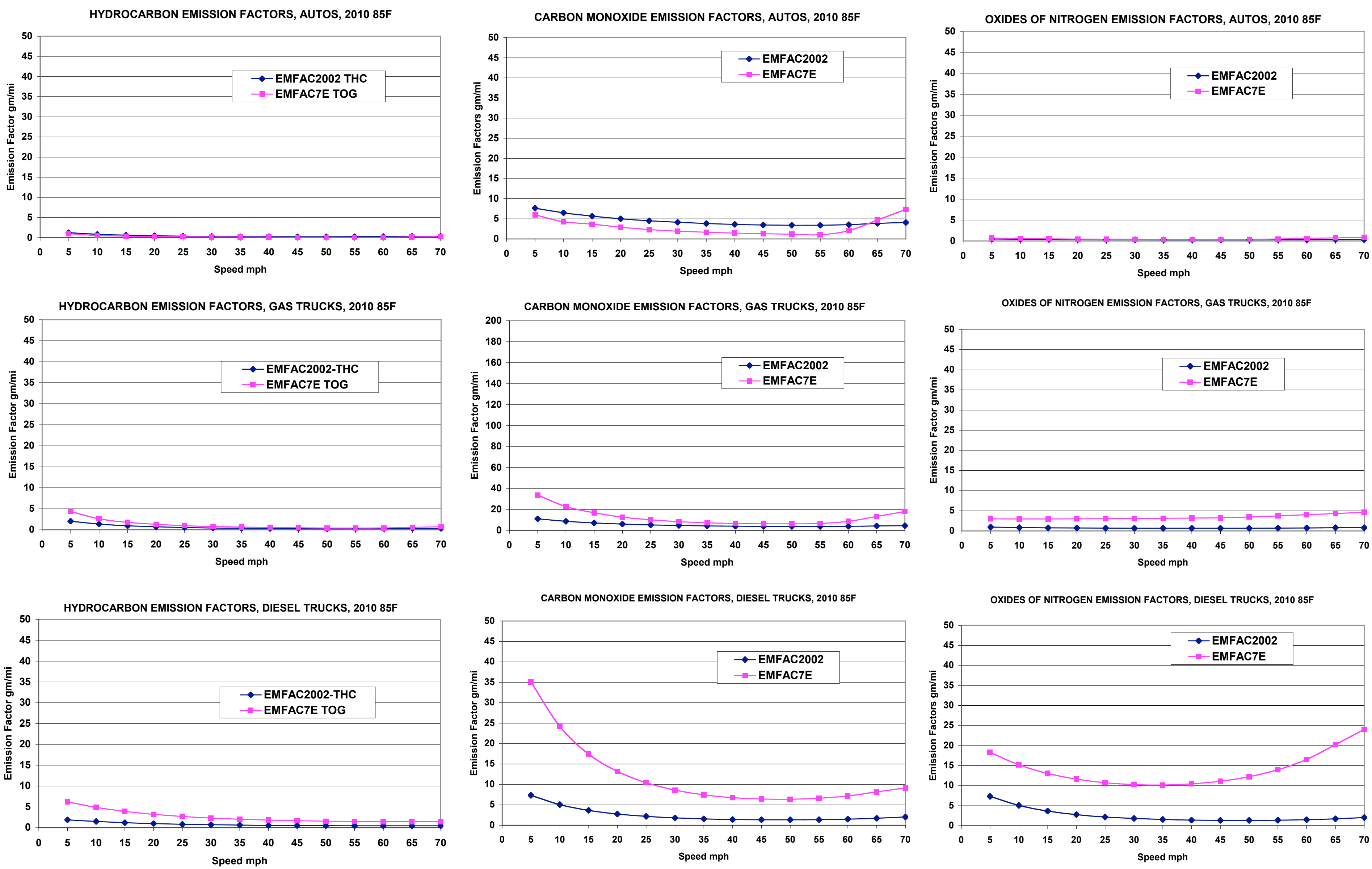

Figure A.11 Comparison of EMFAC7E and EMFAC2002 FREQ Emission Factors for 2010 and 85 Degrees Fahrenheit

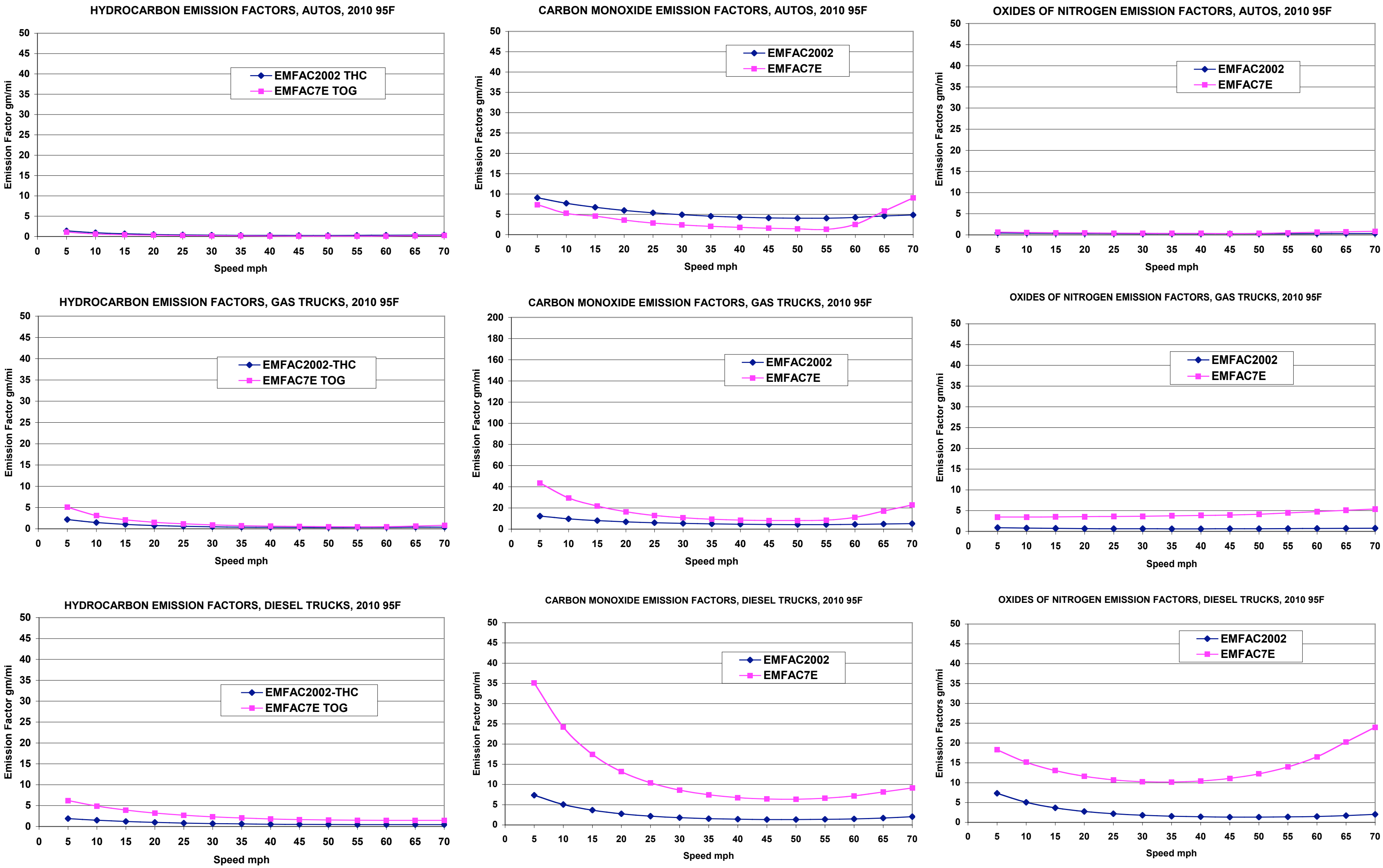

Figure A.12 Comparison of EMFAC7E and EMFAC2002 FREQ Emission Factors for 2010 and 95 Degrees Fahrenheit

APPENDIX B

This appendix contains graphs comparing the new FREQ Emission Rate Tables, which are based on data produced by the California Air Resources Board's EMFAC2002 Emissions Model to data provided by the research team at UC Riverside, which is based on their CMEM Emissions Model. Comparison graphs are included only for the three tables provided by UC Riverside.

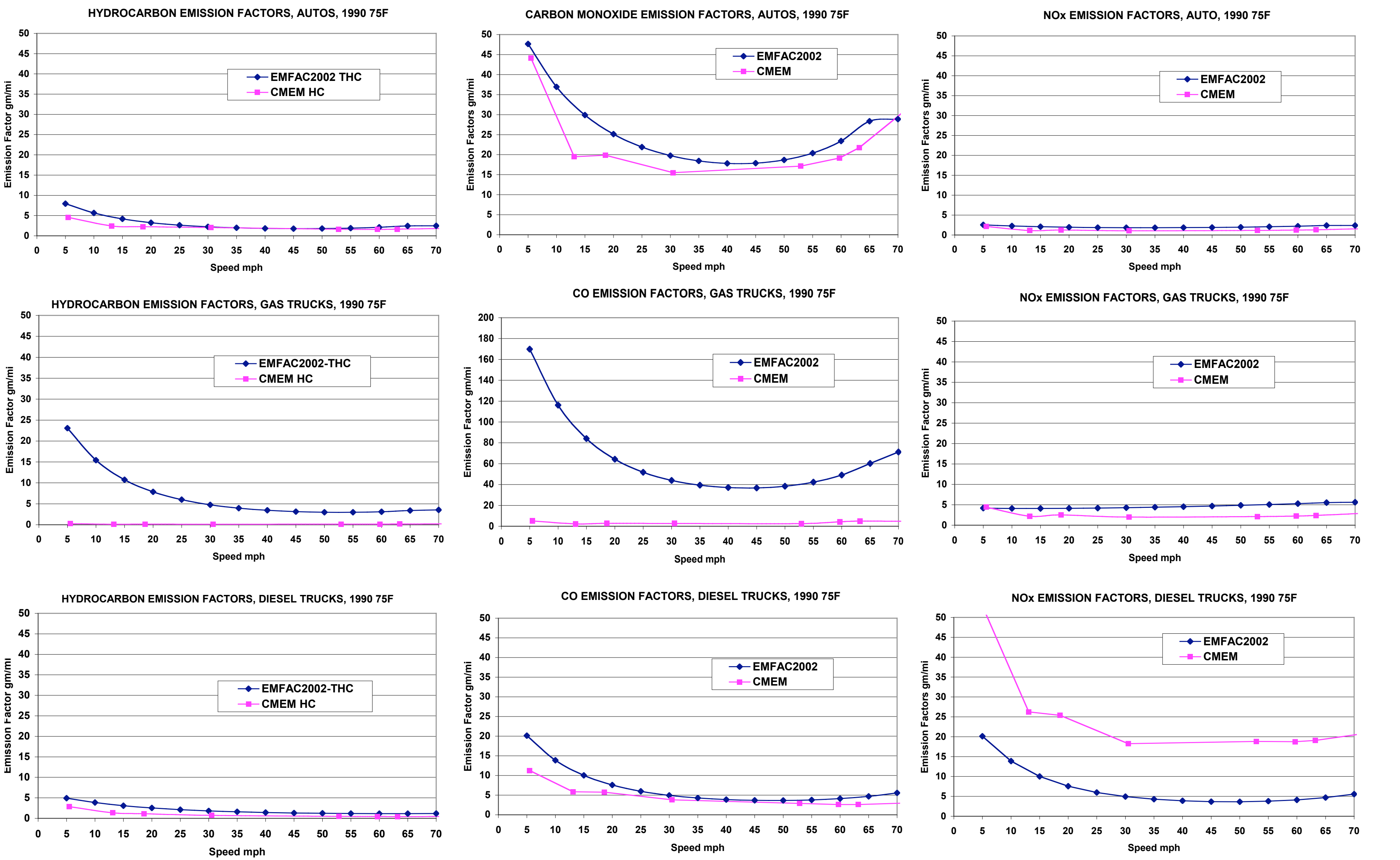

Figure B.1 Comparison of CMEM and EMFAC2002 FREQ Emission Factors for 1990 and 75 Degrees Fahrenheit

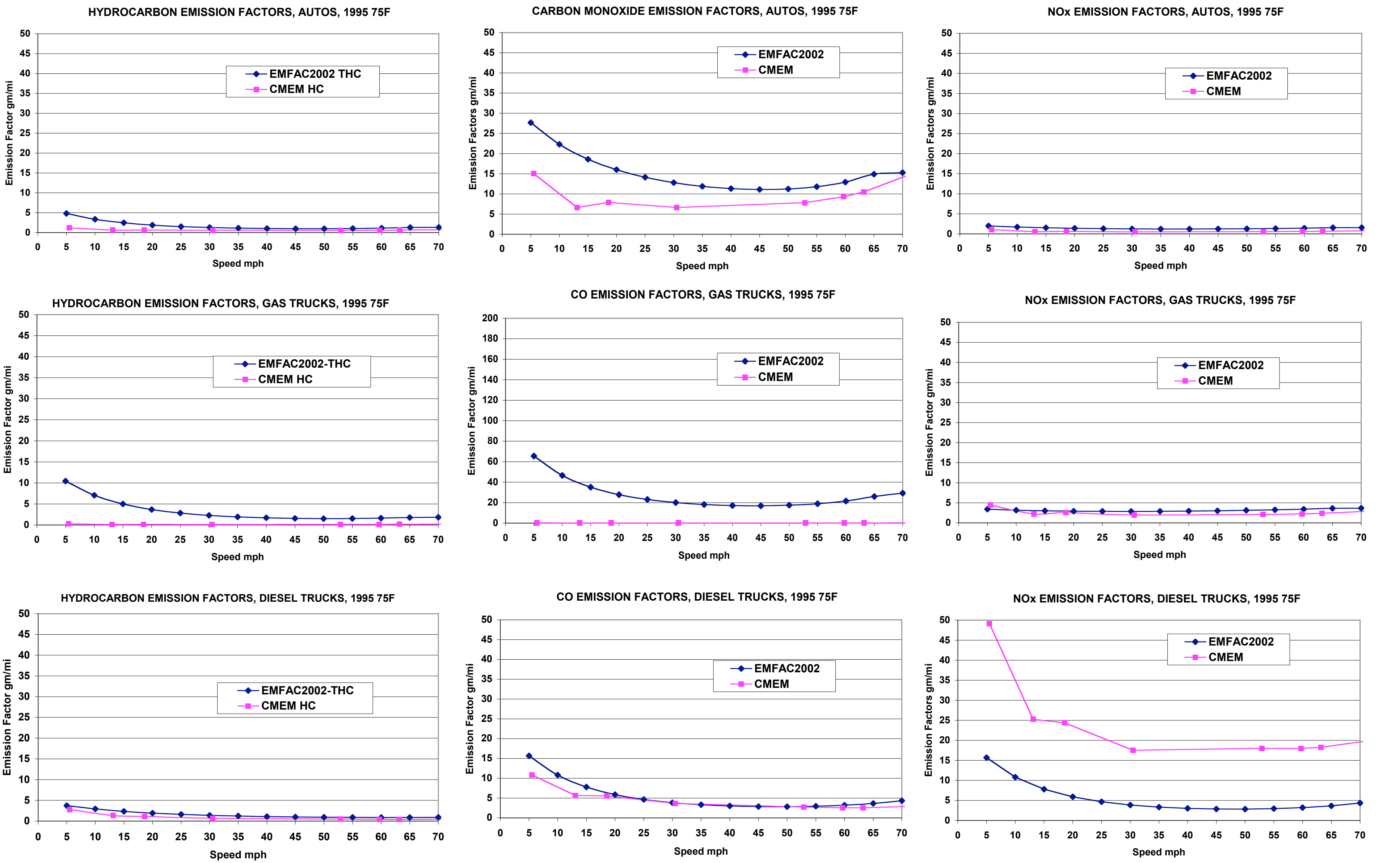

Figure B.2 Comparison of CMEM and EMFAC2002 FREQ Emission Factors for 1995 and 75 Degrees Fahrenheit

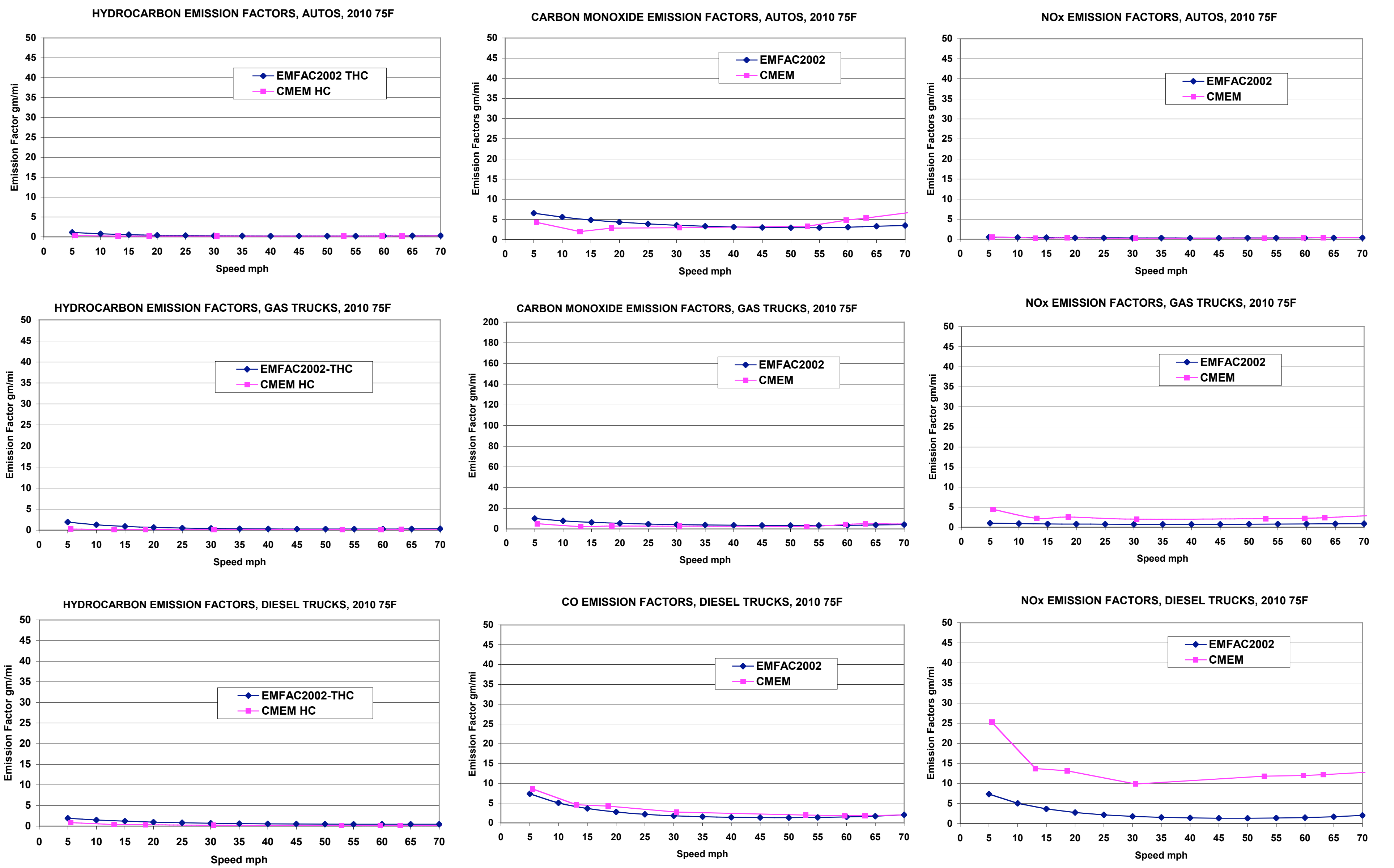

Figure B.3 Comparison of CMEM and EMFAC2002 FREQ Emission Factors for 2010 and 75 Degrees Fahrenheit

APPENDIX C

This appendix contains the new Emission Rate Tables that are embedded in the FREQ model. The tables were developed, using data produced by the California Air Resources Board's EMFAC2002 Emissions Model. There are forty-two tables, one for each combination of seven years (1990, 1995, 2000, 2005, 2010, 2015, and 2020) and six temperatures (55, 65, 75, 85, 95, and 105 degrees Fahrenheit).

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 1990-Annual - 55 Degrees (F) - 40% Humidity

Grams per mile for average travel speeds (mph) of specific pollutant; grams/minute "IDLE"*

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE"*
Total Hydrocarbons															
Autos	8.846	6.284	4.669	3.627	2.945	2.500	2.218	2.058	1.996	2.026	2.152	2.392	2.784	2.838	0.737
Gas trucks	24.995	16.726	11.692	8.539	6.518	5.200	4.337	3.783	3.451	3.296	3.294	3.449	3.783	3.925	2.083
Diesel trucks	4.907	3.851	3.091	2.536	2.126	1.823	1.597	1.431	1.311	1.227	1.174	1.148	1.148	1.174	0.409
Carbon Monoxide															
Autos	51.719	39.756	31.936	26.719	23.225	20.943	19.587	19.016	19.204	20.235	22.332	25.923	31.779	32.476	4.310
Gas trucks	193.876	132.402	95.610	72.938	58.726	49.859	44.608	42.042	41.743	43.680	48.203	56.140	69.056	81.594	16.156
Diesel trucks	20.130	13.880	10.016	7.565	5.978	4.945	4.281	3.878	3.677	3.649	3.789	4.118	4.684	5.576	1.677
Oxides of Nitrogen															
Autos	3.220	2.863	2.624	2.469	2.374	2.327	2.319	2.344	2.402	2.491	2.617	2.786	3.012	3.026	0.268
Gas trucks	5.255	5.145	5.120	5.156	5.237	5.352	5.495	5.663	5.853	6.067	6.306	6.577	6.888	7.029	0.438
Diesel trucks	20.130	13.880	10.016	7.565	5.978	4.945	4.281	3.878	3.677	3.649	3.789	4.118	4.684	5.576	1.677

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.1 FREQ 1990 Emission Rates at 55° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 1990-Annual - 65 Degrees (F) - 40% Humidity

Grams per mile for average travel speeds (mph) of specific pollutant; grams/minute "IDLE"*

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE"*
Total Hydrocarbons															
Autos	8.192	5.817	4.319	3.353	2.720	2.307	2.045	1.895	1.836	1.860	1.972	2.189	2.544	2.592	0.683
Gas trucks	23.804	15.916	11.115	8.110	6.183	4.926	4.103	3.573	3.255	3.102	3.094	3.233	3.538	3.674	1.984
Diesel trucks	4.907	3.851	3.091	2.536	2.126	1.823	1.597	1.431	1.311	1.227	1.174	1.148	1.148	1.174	0.409
Carbon Monoxide															
Autos	47.618	36.752	29.618	24.837	21.616	19.496	18.217	17.651	17.772	18.653	20.491	23.666	28.861	29.463	3.968
Gas trucks	179.513	122.610	88.551	67.559	54.394	46.173	41.293	38.893	38.584	40.332	44.455	51.711	63.530	75.195	14.959
Diesel trucks	20.130	13.880	10.016	7.565	5.978	4.945	4.281	3.878	3.677	3.649	3.789	4.118	4.684	5.576	1.677
Oxides of Nitrogen															
Autos	2.830	2.518	2.308	2.172	2.090	2.049	2.042	2.065	2.116	2.195	2.305	2.455	2.654	2.668	0.236
Gas trucks	4.701	4.609	4.592	4.628	4.704	4.810	4.941	5.092	5.264	5.456	5.671	5.914	6.191	6.319	0.392
Diesel trucks	20.130	13.880	10.016	7.565	5.978	4.945	4.281	3.878	3.677	3.649	3.789	4.118	4.684	5.576	1.677

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.2 FREQ 1990 Emission Rates at 65° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 1990-Annual - 75 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant: 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE"*
Total Hydrocarbons															
Autos	7.947	5.639	4.185	3.246	2.631	2.229	1.973	1.826	1.766	1.787	1.891	2.095	2.431	2.473	0.662
Gas trucks	23.055	15.413	10.762	7.850	5.983	4.765	3.967	3.453	3.143	2.993	2.984	3.114	3.405	3.537	1.921
Diesel trucks	4.907	3.851	3.091	2.536	2.126	1.823	1.597	1.431	1.311	1.227	1.174	1.148	1.148	1.174	0.409
Carbon Monoxide															
Autos	47.641	36.947	29.889	25.132	21.904	19.759	18.442	17.825	17.881	18.676	20.397	23.404	28.348	28.869	3.970
Gas trucks	169.808	116.173	84.042	64.219	51.773	43.989	39.361	37.076	36.766	38.404	42.286	49.131	60.288	71.229	14.151
Diesel trucks	20.130	13.880	10.016	7.565	5.978	4.945	4.281	3.878	3.677	3.649	3.789	4.118	4.684	5.576	1.677
Oxides of Nitrogen															
Autos	2.548	2.265	2.075	1.951	1.876	1.839	1.832	1.852	1.897	1.968	2.068	2.203	2.382	2.394	0.212
Gas trucks	4.197	4.113	4.096	4.127	4.194	4.287	4.403	4.537	4.690	4.861	5.053	5.269	5.517	5.632	0.350
Diesel trucks	20.130	13.880	10.016	7.565	5.978	4.945	4.281	3.878	3.677	3.649	3.789	4.118	4.684	5.576	1.677

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.3 FREQ 1990 Emission Rates at 75° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 1990-Annual - 85 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant: 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE"*
Total Hydrocarbons															
Autos	8.733	6.197	4.598	3.567	2.891	2.450	2.169	2.007	1.942	1.965	2.080	2.305	2.674	2.719	0.728
Gas trucks	24.068	16.107	11.261	8.225	6.278	5.008	4.176	3.641	3.320	3.169	3.165	3.311	3.628	3.764	2.006
Diesel trucks	4.907	3.851	3.091	2.536	2.126	1.823	1.597	1.431	1.311	1.227	1.174	1.148	1.148	1.174	0.409
Carbon Monoxide															
Autos	56.306	43.582	35.203	29.567	25.754	23.229	21.688	20.980	21.073	22.049	24.130	27.750	33.690	34.295	4.692
Gas trucks	187.630	128.552	93.133	71.266	57.532	48.946	43.849	41.349	41.048	42.919	47.304	55.011	67.566	79.451	15.636
Diesel trucks	20.130	13.880	10.016	7.565	5.978	4.945	4.281	3.878	3.677	3.649	3.789	4.118	4.684	5.576	1.677
Oxides of Nitrogen															
Autos	2.375	2.110	1.931	1.815	1.745	1.709	1.702	1.720	1.762	1.827	1.920	2.046	2.213	2.226	0.198
Gas trucks	3.856	3.774	3.755	3.781	3.840	3.924	4.029	4.152	4.291	4.447	4.623	4.821	5.050	5.154	0.321
Diesel trucks	20.130	13.880	10.016	7.565	5.978	4.945	4.281	3.878	3.677	3.649	3.789	4.118	4.684	5.576	1.677

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.4 FREQ 1990 Emission Rates at 85° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 1990-Annual - 95 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	9.947	7.059	5.238	4.064	3.295	2.792	2.473	2.290	2.216	2.243	2.376	2.633	3.056	3.104	0.829
Gas trucks	25.507	17.105	11.984	8.774	6.714	5.370	4.491	3.929	3.595	3.443	3.452	3.625	3.989	4.128	2.126
Diesel trucks	4.907	3.851	3.091	2.536	2.126	1.823	1.597	1.431	1.311	1.227	1.174	1.148	1.148	1.174	0.409
Carbon Monoxide															
Autos	68.173	52.651	42.453	35.612	30.997	27.953	26.108	25.279	25.427	26.653	29.234	33.702	41.019	41.720	5.681
Gas trucks	209.767	144.001	104.528	80.138	64.812	55.233	49.560	46.805	46.528	48.713	53.756	62.592	76.968	89.945	17.481
Diesel trucks	20.130	13.880	10.016	7.565	5.978	4.945	4.281	3.878	3.677	3.649	3.789	4.118	4.684	5.576	1.677
Oxides of Nitrogen															
Autos	2.263	2.004	1.830	1.716	1.646	1.609	1.601	1.616	1.655	1.716	1.804	1.922	2.082	2.094	0.189
Gas trucks	3.498	3.408	3.378	3.391	3.437	3.507	3.596	3.703	3.826	3.965	4.123	4.303	4.512	4.603	0.291
Diesel trucks	20.130	13.880	10.016	7.565	5.978	4.945	4.281	3.878	3.677	3.649	3.789	4.118	4.684	5.576	1.677

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.5 FREQ 1990 Emission Rates at 95° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 1990-Annual - 105 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	10.399	7.383	5.483	4.257	3.455	2.931	2.599	2.409	2.335	2.367	2.511	2.788	3.242	3.291	0.867
Gas trucks	26.699	17.927	12.579	9.224	7.071	5.666	4.749	4.164	3.820	3.668	3.688	3.885	4.290	4.432	2.225
Diesel trucks	4.907	3.851	3.091	2.536	2.126	1.823	1.597	1.431	1.311	1.227	1.174	1.148	1.148	1.174	0.409
Carbon Monoxide															
Autos	65.218	50.059	40.163	33.573	29.166	26.296	24.597	23.891	24.146	25.469	28.143	32.711	40.151	40.964	5.435
Gas trucks	225.819	154.550	111.845	85.503	68.983	58.678	52.590	49.645	49.365	51.727	57.155	66.648	82.080	96.325	18.818
Diesel trucks	20.130	13.880	10.016	7.565	5.978	4.945	4.281	3.878	3.677	3.649	3.789	4.118	4.684	5.576	1.677
Oxides of Nitrogen															
Autos	1.900	1.678	1.529	1.430	1.369	1.337	1.328	1.340	1.371	1.421	1.495	1.595	1.730	1.740	0.158
Gas trucks	2.896	2.814	2.784	2.790	2.824	2.878	2.950	3.036	3.136	3.251	3.381	3.530	3.703	3.777	0.241
Diesel trucks	20.130	13.880	10.016	7.565	5.978	4.945	4.281	3.878	3.677	3.649	3.789	4.118	4.684	5.576	1.677

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.6 FREQ 1990 Emission Rates at 105° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 1995 Annual - 55 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	5.010	3.516	2.584	1.987	1.598	1.343	1.181	1.085	1.042	1.048	1.103	1.215	1.404	1.439	0.418
Gas trucks	10.622	7.190	5.089	3.765	2.913	2.356	1.992	1.762	1.630	1.577	1.599	1.696	1.885	1.930	0.885
Diesel trucks	3.734	2.932	2.353	1.930	1.618	1.388	1.216	1.089	0.998	0.934	0.893	0.874	0.874	0.893	0.311
Carbon Monoxide															
Autos	28.528	22.763	18.845	16.116	14.194	12.852	11.960	11.449	11.301	11.546	12.274	13.661	16.034	16.517	2.377
Gas trucks	68.708	48.771	36.574	28.883	23.944	20.785	18.862	17.884	17.728	18.402	20.051	23.000	27.853	31.191	5.726
Diesel trucks	15.670	10.805	7.797	5.889	4.654	3.850	3.333	3.019	2.862	2.841	2.950	3.206	3.646	4.341	1.306
Oxides of Nitrogen															
Autos	2.493	2.159	1.924	1.760	1.650	1.581	1.545	1.538	1.559	1.608	1.687	1.803	1.966	1.975	0.208
Gas trucks	4.287	3.968	3.766	3.647	3.590	3.580	3.610	3.674	3.769	3.896	4.059	4.264	4.523	4.592	0.357
Diesel trucks	15.670	10.805	7.797	5.889	4.654	3.850	3.333	3.019	2.862	2.841	2.950	3.206	3.646	4.341	1.306

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.7 FREQ 1995 Emission Rates at 55° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 1995 Annual - 65 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	4.792	3.359	2.465	1.893	1.520	1.276	1.120	1.027	0.985	0.988	1.038	1.141	1.315	1.347	0.399
Gas trucks	10.397	7.028	4.966	3.668	2.833	2.287	1.930	1.703	1.571	1.517	1.533	1.621	1.797	1.842	0.866
Diesel trucks	3.734	2.932	2.353	1.930	1.618	1.388	1.216	1.089	0.998	0.934	0.893	0.874	0.874	0.893	0.311
Carbon Monoxide															
Autos	26.873	21.544	17.899	15.344	13.532	12.255	11.394	10.885	10.709	10.893	11.514	12.730	14.829	15.248	2.239
Gas trucks	65.843	46.735	35.046	27.673	22.934	19.896	18.037	17.079	16.899	17.502	19.022	21.759	26.275	29.537	5.487
Diesel trucks	15.670	10.805	7.797	5.889	4.654	3.850	3.333	3.019	2.862	2.841	2.950	3.206	3.646	4.341	1.306
Oxides of Nitrogen															
Autos	2.188	1.895	1.689	1.546	1.450	1.389	1.357	1.352	1.370	1.413	1.483	1.585	1.729	1.737	0.182
Gas trucks	3.805	3.529	3.354	3.252	3.205	3.199	3.228	3.286	3.372	3.486	3.631	3.814	4.042	4.106	0.317
Diesel trucks	15.670	10.805	7.797	5.889	4.654	3.850	3.333	3.019	2.862	2.841	2.950	3.206	3.646	4.341	1.306

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.8 FREQ 1995 Emission Rates at 65° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 1995 Annual - 75 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE"*
Total Hydrocarbons															
Autos	4.804	3.363	2.465	1.890	1.515	1.270	1.113	1.019	0.975	0.976	1.022	1.122	1.290	1.318	0.400
Gas trucks	10.446	7.057	4.984	3.680	2.839	2.290	1.930	1.702	1.568	1.512	1.526	1.612	1.783	1.828	0.870
Diesel trucks	3.734	2.932	2.353	1.930	1.618	1.388	1.216	1.089	0.998	0.934	0.893	0.874	0.874	0.893	0.311
Carbon Monoxide															
Autos	27.678	22.311	18.613	16.000	14.131	12.801	11.888	11.329	11.102	11.232	11.790	12.924	14.910	15.273	2.306
Gas trucks	65.490	46.635	35.079	27.771	23.060	20.028	18.160	17.181	16.970	17.531	18.992	21.646	26.039	29.250	5.458
Diesel trucks	15.670	10.805	7.797	5.889	4.654	3.850	3.333	3.019	2.862	2.841	2.950	3.206	3.646	4.341	1.306
Oxides of Nitrogen															
Autos	1.975	1.710	1.523	1.393	1.306	1.250	1.222	1.217	1.233	1.271	1.335	1.427	1.556	1.565	0.165
Gas trucks	3.417	3.166	3.007	2.915	2.871	2.864	2.889	2.941	3.017	3.120	3.250	3.413	3.618	3.675	0.285
Diesel trucks	15.670	10.805	7.797	5.889	4.654	3.850	3.333	3.019	2.862	2.841	2.950	3.206	3.646	4.341	1.306

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.9 FREQ 1995 Emission Rates at 75° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 1995 Annual - 85 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE"*
Total Hydrocarbons															
Autos	5.257	3.680	2.698	2.069	1.659	1.391	1.218	1.115	1.068	1.069	1.120	1.229	1.413	1.443	0.438
Gas trucks	10.980	7.429	5.256	3.887	3.005	2.428	2.051	1.811	1.674	1.617	1.635	1.731	1.920	1.966	0.915
Diesel trucks	3.734	2.932	2.353	1.930	1.618	1.388	1.216	1.089	0.998	0.934	0.893	0.874	0.874	0.893	0.311
Carbon Monoxide															
Autos	32.403	26.073	21.723	18.657	16.469	14.917	13.857	13.214	12.965	13.135	13.815	15.180	17.560	17.980	2.700
Gas trucks	71.565	51.154	38.614	30.666	25.532	22.224	20.187	19.124	18.909	19.548	21.189	24.162	29.080	32.432	5.964
Diesel trucks	15.670	10.805	7.797	5.889	4.654	3.850	3.333	3.019	2.862	2.841	2.950	3.206	3.646	4.341	1.306
Oxides of Nitrogen															
Autos	1.847	1.598	1.423	1.301	1.219	1.167	1.139	1.134	1.149	1.185	1.244	1.330	1.451	1.459	0.154
Gas trucks	3.163	2.927	2.776	2.687	2.645	2.638	2.659	2.705	2.776	2.869	2.988	3.140	3.330	3.381	0.264
Diesel trucks	15.670	10.805	7.797	5.889	4.654	3.850	3.333	3.019	2.862	2.841	2.950	3.206	3.646	4.341	1.306

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.10 FREQ 1995 Emission Rates at 85° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 1995 Annual - 95 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	5.920	4.146	3.040	2.332	1.871	1.569	1.375	1.260	1.207	1.210	1.268	1.392	1.601	1.633	0.493
Gas trucks	11.820	8.018	5.688	4.219	3.272	2.652	2.249	1.993	1.847	1.793	1.820	1.935	2.156	2.202	0.985
Diesel trucks	3.734	2.932	2.353	1.930	1.618	1.388	1.216	1.089	0.998	0.934	0.893	0.874	0.874	0.893	0.311
Carbon Monoxide															
Autos	38.834	31.176	25.929	22.243	19.622	17.770	16.513	15.759	15.482	15.715	16.567	18.256	21.183	21.670	3.236
Gas trucks	79.679	57.207	43.359	34.559	28.863	25.188	22.928	21.759	21.545	22.301	24.199	27.621	33.277	36.791	6.640
Diesel trucks	15.670	10.805	7.797	5.889	4.654	3.850	3.333	3.019	2.862	2.841	2.950	3.206	3.646	4.341	1.306
Oxides of Nitrogen															
Autos	1.776	1.534	1.364	1.245	1.164	1.113	1.086	1.080	1.094	1.127	1.183	1.266	1.382	1.390	0.148
Gas trucks	2.949	2.715	2.563	2.471	2.423	2.411	2.425	2.464	2.526	2.611	2.721	2.861	3.039	3.084	0.246
Diesel trucks	15.670	10.805	7.797	5.889	4.654	3.850	3.333	3.019	2.862	2.841	2.950	3.206	3.646	4.341	1.306

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.11 FREQ 1995 Emission Rates at 95° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 1995 Annual - 105 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	5.984	4.197	3.083	2.369	1.904	1.600	1.405	1.290	1.238	1.244	1.307	1.439	1.659	1.692	0.499
Gas trucks	12.298	8.357	5.940	4.415	3.431	2.789	2.370	2.108	1.961	1.909	1.945	2.075	2.321	2.368	1.025
Diesel trucks	3.734	2.932	2.353	1.930	1.618	1.388	1.216	1.089	0.998	0.934	0.893	0.874	0.874	0.893	0.311
Carbon Monoxide															
Autos	35.835	28.533	23.583	20.144	17.730	16.049	14.939	14.309	14.139	14.466	15.406	17.183	20.211	20.775	2.986
Gas trucks	80.992	57.733	43.464	34.444	28.644	24.933	22.679	21.549	21.400	22.252	24.285	27.902	33.843	37.546	6.749
Diesel trucks	15.670	10.805	7.797	5.889	4.654	3.850	3.333	3.019	2.862	2.841	2.950	3.206	3.646	4.341	1.306
Oxides of Nitrogen															
Autos	1.495	1.290	1.145	1.044	0.975	0.931	0.908	0.903	0.914	0.943	0.990	1.059	1.158	1.165	0.125
Gas trucks	2.464	2.263	2.133	2.053	2.010	1.997	2.008	2.039	2.090	2.160	2.251	2.369	2.518	2.555	0.205
Diesel trucks	15.670	10.805	7.797	5.889	4.654	3.850	3.333	3.019	2.862	2.841	2.950	3.206	3.646	4.341	1.306

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.12 FREQ 1995 Emission Rates at 105° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2000 Annual - 55 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant: 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
Total Hydrocarbons															
Autos	3.593	2.487	1.805	1.373	1.093	0.911	0.794	0.724	0.691	0.690	0.722	0.791	0.910	0.929	0.299
Gas trucks	5.981	4.063	2.888	2.148	1.671	1.360	1.157	1.029	0.958	0.934	0.952	1.017	1.138	1.157	0.498
Diesel trucks	3.160	2.480	1.990	1.633	1.369	1.174	1.029	0.922	0.844	0.790	0.756	0.739	0.739	0.756	0.263
Carbon Monoxide															
Autos	18.041	14.760	12.461	10.808	9.601	8.720	8.094	7.683	7.475	7.484	7.748	8.357	9.470	9.731	1.503
Gas trucks	32.017	23.631	18.366	14.952	12.693	11.199	10.249	9.727	9.582	9.823	10.521	11.827	14.022	15.140	2.668
Diesel trucks	12.614	8.698	6.276	4.740	3.746	3.099	2.683	2.430	2.304	2.287	2.375	2.581	2.935	3.494	1.051
Oxides of Nitrogen															
Autos	1.895	1.628	1.435	1.299	1.204	1.140	1.103	1.088	1.095	1.124	1.175	1.255	1.370	1.376	0.158
Gas trucks	3.206	2.885	2.668	2.524	2.436	2.391	2.380	2.399	2.447	2.524	2.632	2.777	2.969	3.005	0.267
Diesel trucks	12.614	8.698	6.276	4.740	3.746	3.099	2.683	2.430	2.304	2.287	2.375	2.581	2.935	3.494	1.051

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.13 FREQ 2000 Emission Rates at 55° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2000 Annual - 65 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant: 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
Total Hydrocarbons															
Autos	3.505	2.422	1.755	1.333	1.060	0.882	0.767	0.698	0.665	0.663	0.693	0.757	0.869	0.886	0.292
Gas trucks	5.951	4.034	2.862	2.125	1.649	1.339	1.137	1.009	0.937	0.910	0.925	0.985	1.100	1.119	0.496
Diesel trucks	3.160	2.480	1.990	1.633	1.369	1.174	1.029	0.922	0.844	0.790	0.756	0.739	0.739	0.756	0.263
Carbon Monoxide															
Autos	17.199	14.137	11.976	10.411	9.259	8.411	7.801	7.392	7.172	7.150	7.362	7.886	8.863	9.091	1.433
Gas trucks	31.336	23.101	17.935	14.587	12.371	10.901	9.962	9.436	9.274	9.481	10.121	11.335	13.386	14.541	2.611
Diesel trucks	12.614	8.698	6.276	4.740	3.746	3.099	2.683	2.430	2.304	2.287	2.375	2.581	2.935	3.494	1.051
Oxides of Nitrogen															
Autos	1.662	1.428	1.260	1.140	1.056	1.001	0.968	0.956	0.962	0.987	1.033	1.103	1.204	1.211	0.139
Gas trucks	2.835	2.556	2.367	2.243	2.168	2.129	2.121	2.140	2.183	2.252	2.347	2.477	2.646	2.679	0.236
Diesel trucks	12.614	8.698	6.276	4.740	3.746	3.099	2.683	2.430	2.304	2.287	2.375	2.581	2.935	3.494	1.051

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.14 FREQ 2000 Emission Rates at 65° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2000 Annual - 75 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	3.577	2.468	1.786	1.355	1.075	0.893	0.776	0.705	0.670	0.667	0.695	0.759	0.869	0.884	0.298
Gas trucks	6.096	4.129	2.926	2.170	1.682	1.364	1.156	1.025	0.950	0.921	0.935	0.994	1.107	1.127	0.508
Diesel trucks	3.160	2.480	1.990	1.633	1.369	1.174	1.029	0.922	0.844	0.790	0.756	0.739	0.739	0.756	0.263
Carbon Monoxide															
Autos	17.971	14.852	12.633	11.012	9.808	8.912	8.258	7.808	7.548	7.487	7.657	8.130	9.041	9.241	1.498
Gas trucks	32.188	23.804	18.534	15.108	12.831	11.312	10.332	9.771	9.577	9.755	10.365	11.545	13.554	14.747	2.682
Diesel trucks	12.614	8.698	6.276	4.740	3.746	3.099	2.683	2.430	2.304	2.287	2.375	2.581	2.935	3.494	1.051
Oxides of Nitrogen															
Autos	1.503	1.291	1.139	1.030	0.954	0.904	0.874	0.863	0.868	0.891	0.932	0.995	1.087	1.093	0.125
Gas trucks	2.555	2.303	2.131	2.018	1.949	1.913	1.906	1.923	1.961	2.022	2.109	2.225	2.378	2.408	0.213
Diesel trucks	12.614	8.698	6.276	4.740	3.746	3.099	2.683	2.430	2.304	2.287	2.375	2.581	2.935	3.494	1.051

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.15 FREQ 2000 Emission Rates at 75° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2000 Annual - 85 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	3.903	2.693	1.949	1.478	1.173	0.975	0.847	0.770	0.732	0.729	0.759	0.829	0.949	0.965	0.325
Gas trucks	6.435	4.364	3.098	2.301	1.787	1.451	1.232	1.094	1.016	0.988	1.004	1.069	1.194	1.214	0.536
Diesel trucks	3.160	2.480	1.990	1.633	1.369	1.174	1.029	0.922	0.844	0.790	0.756	0.739	0.739	0.756	0.263
Carbon Monoxide															
Autos	20.965	17.301	14.700	12.804	11.400	10.358	9.600	9.082	8.788	8.726	8.939	9.511	10.604	10.833	1.747
Gas trucks	35.152	26.154	20.471	16.760	14.283	12.626	11.554	10.940	10.730	10.932	11.616	12.935	15.183	16.378	2.929
Diesel trucks	12.614	8.698	6.276	4.740	3.746	3.099	2.683	2.430	2.304	2.287	2.375	2.581	2.935	3.494	1.051
Oxides of Nitrogen															
Autos	1.408	1.209	1.066	0.964	0.893	0.845	0.817	0.806	0.812	0.833	0.871	0.931	1.016	1.022	0.117
Gas trucks	2.378	2.140	1.978	1.870	1.805	1.771	1.763	1.777	1.812	1.869	1.948	2.056	2.199	2.226	0.198
Diesel trucks	12.614	8.698	6.276	4.740	3.746	3.099	2.683	2.430	2.304	2.287	2.375	2.581	2.935	3.494	1.051

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.16 FREQ 2000 Emission Rates at 85° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2000 Annual - 95 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	4.352	3.005	2.175	1.651	1.311	1.090	0.947	0.861	0.820	0.816	0.851	0.930	1.064	1.082	0.363
Gas trucks	6.947	4.722	3.359	2.501	1.948	1.586	1.351	1.203	1.121	1.092	1.114	1.190	1.333	1.353	0.579
Diesel trucks	3.160	2.480	1.990	1.633	1.369	1.174	1.029	0.922	0.844	0.790	0.756	0.739	0.739	0.756	0.263
Carbon Monoxide															
Autos	24.989	20.581	17.462	15.196	13.523	12.285	11.388	10.781	10.442	10.385	10.659	11.371	12.715	12.978	2.082
Gas trucks	39.210	29.360	23.107	19.003	16.253	14.408	13.212	12.529	12.301	12.541	13.332	14.853	17.441	18.639	3.267
Diesel trucks	12.614	8.698	6.276	4.740	3.746	3.099	2.683	2.430	2.304	2.287	2.375	2.581	2.935	3.494	1.051
Oxides of Nitrogen															
Autos	1.360	1.166	1.027	0.928	0.859	0.812	0.785	0.774	0.778	0.798	0.835	0.891	0.974	0.980	0.113
Gas trucks	2.247	2.012	1.852	1.745	1.677	1.641	1.631	1.641	1.672	1.723	1.798	1.899	2.034	2.058	0.187
Diesel trucks	12.614	8.698	6.276	4.740	3.746	3.099	2.683	2.430	2.304	2.287	2.375	2.581	2.935	3.494	1.051

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.17 FREQ 2000 Emission Rates at 95° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2000 Annual - 105 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	4.278	2.960	2.148	1.633	1.299	1.082	0.943	0.859	0.819	0.817	0.854	0.935	1.073	1.091	0.357
Gas trucks	7.056	4.806	3.425	2.555	1.993	1.627	1.389	1.240	1.158	1.133	1.159	1.242	1.395	1.415	0.588
Diesel trucks	3.160	2.480	1.990	1.633	1.369	1.174	1.029	0.922	0.844	0.790	0.756	0.739	0.739	0.756	0.263
Carbon Monoxide															
Autos	22.496	18.370	15.488	13.420	11.914	10.818	10.042	9.538	9.288	9.309	9.654	10.433	11.849	12.153	1.875
Gas trucks	37.859	28.088	21.928	17.920	15.260	13.497	12.379	11.767	11.608	11.916	12.778	14.381	17.073	18.274	3.155
Diesel trucks	12.614	8.698	6.276	4.740	3.746	3.099	2.683	2.430	2.304	2.287	2.375	2.581	2.935	3.494	1.051
Oxides of Nitrogen															
Autos	1.144	0.980	0.863	0.779	0.720	0.680	0.657	0.647	0.651	0.667	0.699	0.747	0.817	0.822	0.095
Gas trucks	1.877	1.678	1.541	1.450	1.393	1.361	1.351	1.360	1.384	1.428	1.489	1.574	1.687	1.706	0.156
Diesel trucks	12.614	8.698	6.276	4.740	3.746	3.099	2.683	2.430	2.304	2.287	2.375	2.581	2.935	3.494	1.051

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.18 FREQ 2000 Emission Rates at 105° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2005 Annual - 55 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant: 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE"*
Total Hydrocarbons															
Autos	1.913	1.316	0.951	0.721	0.573	0.478	0.418	0.382	0.366	0.368	0.388	0.428	0.497	0.515	0.159
Gas trucks	3.528	2.379	1.680	1.241	0.960	0.777	0.658	0.583	0.540	0.525	0.533	0.569	0.635	0.646	0.294
Diesel trucks	2.558	2.008	1.612	1.322	1.109	0.951	0.833	0.747	0.683	0.639	0.612	0.599	0.599	0.612	0.213
Carbon Monoxide															
Autos	10.156	8.445	7.225	6.329	5.661	5.161	4.793	4.539	4.393	4.362	4.469	4.761	5.325	5.566	0.846
Gas trucks	18.286	13.694	10.785	8.877	7.593	6.722	6.147	5.800	5.657	5.715	6.009	6.612	7.662	8.308	1.524
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809
Oxides of Nitrogen															
Autos	1.025	0.886	0.784	0.711	0.658	0.623	0.602	0.592	0.593	0.606	0.630	0.668	0.724	0.729	0.085
Gas trucks	1.997	1.805	1.673	1.585	1.530	1.501	1.492	1.502	1.530	1.574	1.636	1.720	1.831	1.855	0.166
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.19 FREQ 2005 Emission Rates at 55° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2005 Annual - 65 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant: 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE"*
Total Hydrocarbons															
Autos	1.866	1.282	0.924	0.700	0.556	0.462	0.403	0.368	0.352	0.353	0.371	0.410	0.475	0.491	0.155
Gas trucks	3.530	2.377	1.675	1.236	0.954	0.770	0.651	0.575	0.532	0.515	0.523	0.555	0.619	0.631	0.294
Diesel trucks	2.558	2.008	1.612	1.322	1.109	0.951	0.833	0.747	0.683	0.639	0.612	0.599	0.599	0.612	0.213
Carbon Monoxide															
Autos	9.726	8.125	6.975	6.123	5.483	4.999	4.639	4.386	4.233	4.185	4.264	4.509	4.999	5.211	0.811
Gas trucks	17.996	13.462	10.593	8.712	7.446	6.586	6.015	5.667	5.514	5.557	5.825	6.386	7.371	8.037	1.500
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809
Oxides of Nitrogen															
Autos	0.900	0.778	0.688	0.624	0.579	0.548	0.529	0.520	0.521	0.533	0.554	0.588	0.638	0.643	0.075
Gas trucks	1.769	1.601	1.487	1.411	1.363	1.339	1.333	1.342	1.367	1.407	1.462	1.537	1.635	1.657	0.147
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.20 FREQ 2005 Emission Rates at 65° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2005 Annual - 75 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
Total Hydrocarbons															
Autos	1.903	1.304	0.939	0.710	0.562	0.467	0.406	0.370	0.353	0.354	0.371	0.408	0.472	0.487	0.159
Gas trucks	3.626	2.439	1.717	1.266	0.976	0.787	0.664	0.587	0.542	0.524	0.531	0.563	0.626	0.638	0.302
Diesel trucks	2.558	2.008	1.612	1.322	1.109	0.951	0.833	0.747	0.683	0.639	0.612	0.599	0.599	0.612	0.213
Carbon Monoxide															
Autos	10.231	8.597	7.410	6.523	5.849	5.334	4.946	4.665	4.485	4.410	4.459	4.669	5.112	5.300	0.853
Gas trucks	18.619	13.986	11.047	9.112	7.802	6.907	6.306	5.933	5.758	5.780	6.027	6.567	7.527	8.215	1.552
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809
Oxides of Nitrogen															
Autos	0.815	0.704	0.624	0.565	0.524	0.495	0.478	0.470	0.472	0.481	0.501	0.532	0.577	0.581	0.068
Gas trucks	1.596	1.444	1.340	1.271	1.228	1.206	1.199	1.208	1.229	1.265	1.315	1.382	1.471	1.491	0.133
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.21 FREQ 2005 Emission Rates at 75° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2005 Annual - 85 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
Total Hydrocarbons															
Autos	2.074	1.421	1.023	0.773	0.612	0.508	0.442	0.403	0.385	0.385	0.404	0.445	0.514	0.529	0.173
Gas trucks	3.813	2.568	1.810	1.336	1.031	0.833	0.704	0.622	0.576	0.558	0.566	0.602	0.671	0.683	0.318
Diesel trucks	2.558	2.008	1.612	1.322	1.109	0.951	0.833	0.747	0.683	0.639	0.612	0.599	0.599	0.612	0.213
Carbon Monoxide															
Autos	11.949	10.028	8.636	7.599	6.812	6.212	5.760	5.435	5.229	5.146	5.209	5.463	5.993	6.206	0.996
Gas trucks	20.337	15.386	12.227	10.134	8.710	7.731	7.071	6.659	6.464	6.485	6.756	7.353	8.414	9.103	1.695
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809
Oxides of Nitrogen															
Autos	0.765	0.661	0.585	0.530	0.491	0.464	0.448	0.441	0.442	0.451	0.469	0.498	0.540	0.545	0.064
Gas trucks	1.486	1.343	1.245	1.180	1.138	1.116	1.110	1.117	1.137	1.170	1.216	1.278	1.361	1.379	0.124
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.22 FREQ 2005 Emission Rates at 85° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2005 Annual - 95 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant: 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
Total Hydrocarbons															
Autos	2.302	1.578	1.136	0.859	0.680	0.565	0.491	0.448	0.428	0.428	0.449	0.494	0.571	0.588	0.192
Gas trucks	4.076	2.749	1.941	1.435	1.110	0.899	0.762	0.675	0.626	0.608	0.619	0.660	0.737	0.749	0.340
Diesel trucks	2.558	2.008	1.612	1.322	1.109	0.951	0.833	0.747	0.683	0.639	0.612	0.599	0.599	0.612	0.213
Carbon Monoxide															
Autos	14.227	11.922	10.256	9.018	8.081	7.368	6.833	6.450	6.209	6.118	6.201	6.515	7.162	7.407	1.186
Gas trucks	22.647	17.263	13.804	11.498	9.920	8.830	8.091	7.628	7.408	7.432	7.739	8.415	9.621	10.311	1.887
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809
Oxides of Nitrogen															
Autos	0.739	0.638	0.565	0.511	0.473	0.447	0.431	0.423	0.424	0.433	0.451	0.478	0.519	0.523	0.062
Gas trucks	1.404	1.263	1.166	1.100	1.058	1.035	1.026	1.031	1.049	1.077	1.121	1.179	1.257	1.273	0.117
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.23 FREQ 2005 Emission Rates at 95° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2005 Annual - 105 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant: 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
Total Hydrocarbons															
Autos	2.235	1.536	1.109	0.840	0.667	0.555	0.484	0.442	0.423	0.424	0.445	0.492	0.569	0.586	0.186
Gas trucks	4.055	2.738	1.937	1.434	1.111	0.901	0.765	0.679	0.631	0.614	0.625	0.668	0.748	0.761	0.338
Diesel trucks	2.558	2.008	1.612	1.322	1.109	0.951	0.833	0.747	0.683	0.639	0.612	0.599	0.599	0.612	0.213
Carbon Monoxide															
Autos	12.582	10.449	8.930	7.818	6.989	6.370	5.916	5.604	5.426	5.391	5.527	5.894	6.599	6.879	1.049
Gas trucks	21.453	16.162	12.795	10.575	9.076	8.056	7.379	6.973	6.805	6.878	7.234	7.961	9.227	9.918	1.788
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809
Oxides of Nitrogen															
Autos	0.620	0.534	0.472	0.427	0.395	0.373	0.359	0.353	0.354	0.361	0.376	0.399	0.433	0.437	0.052
Gas trucks	1.170	1.051	0.968	0.911	0.876	0.856	0.848	0.852	0.866	0.890	0.926	0.974	1.040	1.053	0.097
Diesel trucks	9.704	6.692	4.829	3.647	2.882	2.384	2.064	1.870	1.773	1.759	1.827	1.985	2.258	2.688	0.809

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.24 FREQ 2005 Emission Rates at 105° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2010 Annual - 55 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant: 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
Total Hydrocarbons															
Autos	1.124	0.770	0.555	0.420	0.334	0.279	0.244	0.225	0.216	0.219	0.233	0.260	0.306	0.327	0.094
Gas trucks	1.807	1.207	0.844	0.618	0.474	0.381	0.319	0.281	0.258	0.248	0.250	0.264	0.292	0.298	0.151
Diesel trucks	1.893	1.486	1.193	0.978	0.821	0.704	0.616	0.552	0.506	0.473	0.453	0.443	0.443	0.453	0.158
Carbon Monoxide															
Autos	6.382	5.386	4.662	4.119	3.707	3.391	3.153	2.983	2.878	2.842	2.893	3.058	3.394	3.633	0.532
Gas trucks	9.439	7.334	5.963	5.030	4.373	3.903	3.564	3.329	3.181	3.118	3.147	3.291	3.594	3.912	0.787
Diesel trucks	7.337	5.059	3.651	2.758	2.179	1.803	1.561	1.414	1.341	1.330	1.381	1.501	1.708	2.032	0.611
Oxides of Nitrogen															
Autos	0.634	0.549	0.488	0.443	0.410	0.388	0.374	0.367	0.367	0.373	0.387	0.409	0.440	0.444	0.053
Gas trucks	1.267	1.132	1.036	0.970	0.926	0.899	0.887	0.887	0.898	0.921	0.956	1.006	1.073	1.086	0.106
Diesel trucks	7.337	5.059	3.651	2.758	2.179	1.803	1.561	1.414	1.341	1.330	1.381	1.501	1.708	2.032	0.611

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.25 FREQ 2010 Emission Rates at 55° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2010 Annual - 65 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant: 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
Total Hydrocarbons															
Autos	1.101	0.754	0.542	0.409	0.325	0.271	0.237	0.217	0.209	0.211	0.224	0.250	0.293	0.312	0.092
Gas trucks	1.836	1.225	0.857	0.627	0.480	0.385	0.323	0.283	0.260	0.250	0.252	0.265	0.294	0.300	0.153
Diesel trucks	1.893	1.486	1.193	0.978	0.821	0.704	0.616	0.552	0.506	0.473	0.453	0.443	0.443	0.453	0.158
Carbon Monoxide															
Autos	6.158	5.218	4.529	4.009	3.610	3.303	3.069	2.898	2.789	2.743	2.777	2.914	3.206	3.417	0.513
Gas trucks	9.466	7.343	5.962	5.023	4.364	3.892	3.553	3.317	3.168	3.103	3.131	3.272	3.570	3.898	0.789
Diesel trucks	7.337	5.059	3.651	2.758	2.179	1.803	1.561	1.414	1.341	1.330	1.381	1.501	1.708	2.032	0.611
Oxides of Nitrogen															
Autos	0.557	0.482	0.428	0.388	0.360	0.341	0.328	0.322	0.322	0.328	0.340	0.359	0.387	0.390	0.046
Gas trucks	1.120	1.001	0.918	0.861	0.822	0.799	0.789	0.789	0.800	0.821	0.852	0.896	0.955	0.967	0.093
Diesel trucks	7.337	5.059	3.651	2.758	2.179	1.803	1.561	1.414	1.341	1.330	1.381	1.501	1.708	2.032	0.611

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.26 FREQ 2010 Emission Rates at 65° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2010 Annual - 75 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant														grams/ minute
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	"IDLE"*
Total Hydrocarbons															
Autos	1.131	0.771	0.553	0.417	0.330	0.275	0.240	0.219	0.210	0.212	0.224	0.250	0.293	0.311	0.094
Gas trucks	1.923	1.283	0.897	0.657	0.503	0.404	0.338	0.297	0.273	0.262	0.263	0.278	0.308	0.314	0.160
Diesel trucks	1.893	1.486	1.193	0.978	0.821	0.704	0.616	0.552	0.506	0.473	0.453	0.443	0.443	0.453	0.158
Carbon Monoxide															
Autos	6.550	5.577	4.857	4.309	3.884	3.554	3.298	3.108	2.979	2.915	2.928	3.043	3.304	3.491	0.546
Gas trucks	10.088	7.861	6.405	5.413	4.712	4.207	3.842	3.586	3.423	3.347	3.368	3.510	3.815	4.153	0.841
Diesel trucks	7.337	5.059	3.651	2.758	2.179	1.803	1.561	1.414	1.341	1.330	1.381	1.501	1.708	2.032	0.611
Oxides of Nitrogen															
Autos	0.504	0.437	0.388	0.352	0.326	0.308	0.297	0.291	0.291	0.296	0.307	0.325	0.350	0.353	0.042
Gas trucks	1.012	0.904	0.828	0.776	0.742	0.721	0.711	0.712	0.721	0.739	0.768	0.807	0.860	0.871	0.084
Diesel trucks	7.337	5.059	3.651	2.758	2.179	1.803	1.561	1.414	1.341	1.330	1.381	1.501	1.708	2.032	0.611

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.27 FREQ 2010 Emission Rates at 75° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2010 Annual - 85 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant														grams/ minute
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	"IDLE"*
Total Hydrocarbons															
Autos	1.234	0.842	0.604	0.455	0.361	0.300	0.261	0.239	0.229	0.231	0.244	0.272	0.318	0.336	0.103
Gas trucks	2.036	1.359	0.951	0.698	0.535	0.429	0.361	0.317	0.291	0.281	0.284	0.299	0.332	0.338	0.170
Diesel trucks	1.893	1.486	1.193	0.978	0.821	0.704	0.616	0.552	0.506	0.473	0.453	0.443	0.443	0.453	0.158
Carbon Monoxide															
Autos	7.633	6.495	5.654	5.014	4.519	4.134	3.837	3.616	3.468	3.395	3.412	3.548	3.857	4.070	0.636
Gas trucks	11.024	8.665	7.110	6.039	5.277	4.723	4.319	4.032	3.845	3.754	3.768	3.909	4.229	4.567	0.919
Diesel trucks	7.337	5.059	3.651	2.758	2.179	1.803	1.561	1.414	1.341	1.330	1.381	1.501	1.708	2.032	0.611
Oxides of Nitrogen															
Autos	0.474	0.410	0.364	0.330	0.306	0.289	0.278	0.273	0.273	0.278	0.288	0.304	0.328	0.331	0.040
Gas trucks	0.944	0.842	0.771	0.722	0.689	0.669	0.660	0.659	0.668	0.685	0.711	0.748	0.798	0.808	0.079
Diesel trucks	7.337	5.059	3.651	2.758	2.179	1.803	1.561	1.414	1.341	1.330	1.381	1.501	1.708	2.032	0.611

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.28 FREQ 2010 Emission Rates at 85° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2010 Annual - 95 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	1.373	0.937	0.673	0.507	0.402	0.334	0.291	0.266	0.256	0.257	0.272	0.302	0.353	0.373	0.114
Gas trucks	2.196	1.469	1.030	0.756	0.581	0.467	0.394	0.348	0.320	0.309	0.313	0.332	0.369	0.375	0.183
Diesel trucks	1.893	1.486	1.193	0.978	0.821	0.704	0.616	0.552	0.506	0.473	0.453	0.443	0.443	0.453	0.158
Carbon Monoxide															
Autos	9.081	7.715	6.710	5.947	5.359	4.901	4.549	4.288	4.114	4.031	4.055	4.221	4.596	4.840	0.757
Gas trucks	12.319	9.767	8.069	6.889	6.042	5.422	4.965	4.638	4.421	4.312	4.319	4.471	4.822	5.161	1.027
Diesel trucks	7.337	5.059	3.651	2.758	2.179	1.803	1.561	1.414	1.341	1.330	1.381	1.501	1.708	2.032	0.611
Oxides of Nitrogen															
Autos	0.458	0.397	0.352	0.319	0.295	0.279	0.268	0.263	0.263	0.267	0.277	0.293	0.316	0.319	0.038
Gas trucks	0.898	0.799	0.728	0.679	0.646	0.626	0.616	0.614	0.622	0.638	0.662	0.696	0.744	0.753	0.075
Diesel trucks	7.337	5.059	3.651	2.758	2.179	1.803	1.561	1.414	1.341	1.330	1.381	1.501	1.708	2.032	0.611

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.29 FREQ 2010 Emission Rates at 95° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2010 Annual - 105 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	1.337	0.915	0.659	0.498	0.395	0.329	0.288	0.264	0.254	0.257	0.272	0.303	0.354	0.375	0.111
Gas trucks	2.164	1.450	1.018	0.749	0.577	0.465	0.392	0.347	0.320	0.310	0.315	0.334	0.373	0.379	0.180
Diesel trucks	1.893	1.486	1.193	0.978	0.821	0.704	0.616	0.552	0.506	0.473	0.453	0.443	0.443	0.453	0.158
Carbon Monoxide															
Autos	7.945	6.690	5.781	5.103	4.589	4.196	3.901	3.692	3.564	3.524	3.590	3.800	4.225	4.504	0.662
Gas trucks	11.236	8.786	7.178	6.079	5.302	4.742	4.339	4.059	3.885	3.813	3.855	4.040	4.423	4.762	0.936
Diesel trucks	7.337	5.059	3.651	2.758	2.179	1.803	1.561	1.414	1.341	1.330	1.381	1.501	1.708	2.032	0.611
Oxides of Nitrogen															
Autos	0.384	0.332	0.294	0.266	0.247	0.232	0.224	0.219	0.219	0.223	0.231	0.245	0.264	0.267	0.032
Gas trucks	0.750	0.666	0.606	0.565	0.537	0.520	0.511	0.510	0.516	0.529	0.549	0.579	0.618	0.625	0.063
Diesel trucks	7.337	5.059	3.651	2.758	2.179	1.803	1.561	1.414	1.341	1.330	1.381	1.501	1.708	2.032	0.611

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.30 FREQ 2010 Emission Rates at 105° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2015 Annual - 55 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant: 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE"*
Total Hydrocarbons															
Autos	0.641	0.436	0.312	0.235	0.186	0.155	0.135	0.123	0.119	0.121	0.128	0.144	0.169	0.183	0.053
Gas trucks	1.261	0.840	0.587	0.429	0.329	0.264	0.221	0.195	0.180	0.173	0.175	0.186	0.206	0.210	0.105
Diesel trucks	1.287	1.010	0.811	0.665	0.558	0.478	0.419	0.375	0.344	0.322	0.308	0.301	0.301	0.308	0.107
Carbon Monoxide															
Autos	3.810	3.278	2.876	2.566	2.321	2.127	1.975	1.858	1.775	1.729	1.724	1.776	1.909	2.035	0.318
Gas trucks	6.978	5.449	4.451	3.768	3.286	2.937	2.684	2.505	2.389	2.334	2.345	2.439	2.646	2.879	0.582
Diesel trucks	5.467	3.770	2.720	2.054	1.624	1.343	1.163	1.054	0.999	0.991	1.029	1.118	1.272	1.514	0.456
Oxides of Nitrogen															
Autos	0.387	0.335	0.297	0.268	0.248	0.233	0.224	0.219	0.218	0.222	0.229	0.242	0.261	0.262	0.032
Gas trucks	0.846	0.759	0.698	0.655	0.627	0.610	0.602	0.603	0.610	0.626	0.649	0.681	0.725	0.734	0.071
Diesel trucks	5.467	3.770	2.720	2.054	1.624	1.343	1.163	1.054	0.999	0.991	1.029	1.118	1.272	1.514	0.456

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.31 FREQ 2015 Emission Rates at 55° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2015 Annual - 65 Degrees (F) - 40% Humidity

Vehicle Class	Grams per mile for average travel speeds (mph) of specific pollutant: 5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE"*
Total Hydrocarbons															
Autos	0.635	0.431	0.308	0.231	0.183	0.152	0.132	0.121	0.116	0.117	0.125	0.140	0.164	0.177	0.053
Gas trucks	1.279	0.852	0.595	0.435	0.333	0.267	0.224	0.196	0.181	0.174	0.176	0.186	0.207	0.211	0.107
Diesel trucks	1.287	1.010	0.811	0.665	0.558	0.478	0.419	0.375	0.344	0.322	0.308	0.301	0.301	0.308	0.107
Carbon Monoxide															
Autos	3.718	3.207	2.820	2.518	2.279	2.089	1.937	1.820	1.736	1.686	1.675	1.714	1.829	1.940	0.310
Gas trucks	6.999	5.457	4.450	3.764	3.280	2.929	2.676	2.496	2.379	2.324	2.334	2.426	2.630	2.871	0.583
Diesel trucks	5.467	3.770	2.720	2.054	1.624	1.343	1.163	1.054	0.999	0.991	1.029	1.118	1.272	1.514	0.456
Oxides of Nitrogen															
Autos	0.340	0.294	0.260	0.235	0.217	0.204	0.197	0.192	0.192	0.195	0.201	0.213	0.229	0.231	0.028
Gas trucks	0.747	0.672	0.618	0.581	0.557	0.543	0.536	0.537	0.544	0.558	0.578	0.607	0.645	0.654	0.062
Diesel trucks	5.467	3.770	2.720	2.054	1.624	1.343	1.163	1.054	0.999	0.991	1.029	1.118	1.272	1.514	0.456

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.32 FREQ 2015 Emission Rates at 65° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2015 Annual - 75 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	0.661	0.447	0.319	0.239	0.189	0.156	0.136	0.124	0.119	0.120	0.127	0.142	0.167	0.179	0.055
Gas trucks	1.340	0.892	0.623	0.455	0.348	0.280	0.235	0.206	0.190	0.182	0.185	0.195	0.217	0.221	0.112
Diesel trucks	1.287	1.010	0.811	0.665	0.558	0.478	0.419	0.375	0.344	0.322	0.308	0.301	0.301	0.308	0.107
Carbon Monoxide															
Autos	4.013	3.473	3.060	2.737	2.479	2.271	2.105	1.975	1.879	1.816	1.794	1.822	1.922	2.019	0.334
Gas trucks	7.469	5.850	4.790	4.063	3.547	3.172	2.899	2.704	2.576	2.511	2.516	2.607	2.815	3.063	0.622
Diesel trucks	5.467	3.770	2.720	2.054	1.624	1.343	1.163	1.054	0.999	0.991	1.029	1.118	1.272	1.514	0.456
Oxides of Nitrogen															
Autos	0.308	0.266	0.236	0.213	0.197	0.185	0.178	0.174	0.174	0.176	0.182	0.193	0.207	0.209	0.026
Gas trucks	0.675	0.607	0.558	0.525	0.502	0.489	0.484	0.484	0.490	0.502	0.522	0.547	0.581	0.589	0.056
Diesel trucks	5.467	3.770	2.720	2.054	1.624	1.343	1.163	1.054	0.999	0.991	1.029	1.118	1.272	1.514	0.456

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.33 FREQ 2015 Emission Rates at 75° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2015 Annual - 85 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	0.721	0.489	0.348	0.261	0.206	0.170	0.148	0.135	0.130	0.131	0.138	0.154	0.180	0.193	0.060
Gas trucks	1.422	0.947	0.662	0.484	0.371	0.298	0.251	0.220	0.203	0.196	0.198	0.210	0.235	0.238	0.118
Diesel trucks	1.287	1.010	0.811	0.665	0.558	0.478	0.419	0.375	0.344	0.322	0.308	0.301	0.301	0.308	0.107
Carbon Monoxide															
Autos	4.664	4.036	3.556	3.179	2.880	2.639	2.446	2.295	2.183	2.111	2.084	2.118	2.235	2.346	0.389
Gas trucks	8.174	6.461	5.328	4.543	3.982	3.570	3.267	3.047	2.900	2.822	2.819	2.909	3.124	3.373	0.681
Diesel trucks	5.467	3.770	2.720	2.054	1.624	1.343	1.163	1.054	0.999	0.991	1.029	1.118	1.272	1.514	0.456
Oxides of Nitrogen															
Autos	0.290	0.250	0.222	0.200	0.185	0.174	0.167	0.163	0.163	0.165	0.171	0.180	0.194	0.196	0.024
Gas trucks	0.630	0.566	0.519	0.488	0.467	0.454	0.449	0.448	0.454	0.466	0.483	0.507	0.539	0.546	0.053
Diesel trucks	5.467	3.770	2.720	2.054	1.624	1.343	1.163	1.054	0.999	0.991	1.029	1.118	1.272	1.514	0.456

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.34 FREQ 2015 Emission Rates at 85° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2015 Annual - 95 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
	Total Hydrocarbons														
Autos	0.804	0.545	0.388	0.291	0.230	0.190	0.165	0.151	0.145	0.146	0.154	0.171	0.201	0.214	0.067
Gas trucks	1.538	1.026	0.718	0.527	0.405	0.326	0.275	0.242	0.224	0.217	0.220	0.234	0.262	0.266	0.128
Diesel trucks	1.287	1.010	0.811	0.665	0.558	0.478	0.419	0.375	0.344	0.322	0.308	0.301	0.301	0.308	0.107
	Carbon Monoxide														
Autos	5.535	4.785	4.213	3.766	3.410	3.124	2.896	2.718	2.585	2.502	2.472	2.513	2.656	2.783	0.461
Gas trucks	9.145	7.293	6.056	5.192	4.567	4.104	3.761	3.510	3.340	3.246	3.237	3.330	3.565	3.813	0.762
Diesel trucks	5.467	3.770	2.720	2.054	1.624	1.343	1.163	1.054	0.999	0.991	1.029	1.118	1.272	1.514	0.456
	Oxides of Nitrogen														
Autos	0.281	0.242	0.214	0.194	0.179	0.168	0.161	0.158	0.157	0.159	0.165	0.174	0.188	0.189	0.023
Gas trucks	0.600	0.536	0.490	0.458	0.438	0.425	0.418	0.418	0.422	0.433	0.448	0.471	0.502	0.508	0.050
Diesel trucks	5.467	3.770	2.720	2.054	1.624	1.343	1.163	1.054	0.999	0.991	1.029	1.118	1.272	1.514	0.456

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.35 FREQ 2015 Emission Rates at 95° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2015 Annual - 105 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
	Total Hydrocarbons														
Autos	0.780	0.530	0.379	0.285	0.226	0.187	0.163	0.149	0.143	0.145	0.154	0.171	0.201	0.215	0.065
Gas trucks	1.516	1.014	0.712	0.523	0.403	0.325	0.274	0.242	0.225	0.218	0.222	0.237	0.265	0.269	0.126
Diesel trucks	1.287	1.010	0.811	0.665	0.558	0.478	0.419	0.375	0.344	0.322	0.308	0.301	0.301	0.308	0.107
	Carbon Monoxide														
Autos	4.754	4.077	3.571	3.181	2.875	2.634	2.445	2.302	2.201	2.146	2.145	2.215	2.388	2.535	0.396
Gas trucks	8.290	6.517	5.350	4.548	3.978	3.564	3.262	3.049	2.912	2.848	2.866	2.986	3.245	3.495	0.691
Diesel trucks	5.467	3.770	2.720	2.054	1.624	1.343	1.163	1.054	0.999	0.991	1.029	1.118	1.272	1.514	0.456
	Oxides of Nitrogen														
Autos	0.235	0.203	0.180	0.162	0.149	0.140	0.135	0.132	0.131	0.133	0.138	0.146	0.157	0.159	0.020
Gas trucks	0.500	0.446	0.407	0.381	0.363	0.352	0.347	0.346	0.350	0.359	0.372	0.391	0.416	0.421	0.042
Diesel trucks	5.467	3.770	2.720	2.054	1.624	1.343	1.163	1.054	0.999	0.991	1.029	1.118	1.272	1.514	0.456

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.36 FREQ 2015 Emission Rates at 105° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2020 Annual - 55 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/minute "IDLE"*
							Grams per mile for average travel speeds (mph) of specific pollutant								
							Total Hydrocarbons								
Autos	0.405	0.274	0.195	0.146	0.115	0.095	0.083	0.076	0.074	0.075	0.080	0.091	0.108	0.121	0.034
Gas trucks	0.871	0.579	0.404	0.296	0.227	0.182	0.153	0.134	0.124	0.121	0.122	0.129	0.145	0.147	0.073
Diesel trucks	0.961	0.754	0.605	0.497	0.416	0.357	0.313	0.280	0.257	0.240	0.230	0.225	0.225	0.230	0.080
							Carbon Monoxide								
Autos	2.419	2.125	1.892	1.704	1.552	1.426	1.323	1.241	1.177	1.135	1.115	1.126	1.182	1.285	0.202
Gas trucks	5.262	4.139	3.401	2.894	2.532	2.268	2.071	1.930	1.833	1.780	1.774	1.825	1.954	2.131	0.438
Diesel trucks	4.589	3.164	2.283	1.725	1.363	1.128	0.976	0.884	0.838	0.832	0.864	0.939	1.068	1.271	0.382
							Oxides of Nitrogen								
Autos	0.259	0.223	0.197	0.177	0.163	0.153	0.146	0.142	0.141	0.143	0.148	0.156	0.168	0.169	0.022
Gas trucks	0.579	0.519	0.475	0.446	0.426	0.414	0.408	0.407	0.412	0.421	0.437	0.458	0.488	0.494	0.048
Diesel trucks	4.589	3.164	2.283	1.725	1.363	1.128	0.976	0.884	0.838	0.832	0.864	0.939	1.068	1.271	0.382

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.37 FREQ 2020 Emission Rates at 55° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2020 Annual - 65 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/minute "IDLE"*
							Grams per mile for average travel speeds (mph) of specific pollutant								
							Total Hydrocarbons								
Autos	0.408	0.275	0.195	0.146	0.115	0.095	0.083	0.076	0.074	0.074	0.080	0.090	0.107	0.119	0.034
Gas trucks	0.884	0.587	0.410	0.300	0.229	0.184	0.154	0.136	0.125	0.121	0.123	0.130	0.146	0.148	0.074
Diesel trucks	0.961	0.754	0.605	0.497	0.416	0.357	0.313	0.280	0.257	0.240	0.230	0.225	0.225	0.230	0.080
							Carbon Monoxide								
Autos	2.385	2.098	1.869	1.685	1.534	1.409	1.307	1.224	1.160	1.115	1.092	1.098	1.144	1.234	0.199
Gas trucks	5.287	4.151	3.406	2.895	2.531	2.265	2.068	1.926	1.830	1.776	1.770	1.820	1.948	2.130	0.441
Diesel trucks	4.589	3.164	2.283	1.725	1.363	1.128	0.976	0.884	0.838	0.832	0.864	0.939	1.068	1.271	0.382
							Oxides of Nitrogen								
Autos	0.227	0.196	0.173	0.155	0.143	0.134	0.128	0.125	0.124	0.126	0.130	0.137	0.147	0.148	0.019
Gas trucks	0.512	0.459	0.422	0.396	0.378	0.367	0.362	0.362	0.367	0.376	0.389	0.408	0.434	0.439	0.043
Diesel trucks	4.589	3.164	2.283	1.725	1.363	1.128	0.976	0.884	0.838	0.832	0.864	0.939	1.068	1.271	0.382

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.38 FREQ 2020 Emission Rates at 65° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2020 Annual - 75 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	0.429	0.288	0.205	0.153	0.121	0.100	0.086	0.079	0.076	0.077	0.082	0.092	0.109	0.121	0.036
Gas trucks	0.928	0.616	0.429	0.314	0.240	0.193	0.162	0.143	0.131	0.127	0.128	0.137	0.152	0.155	0.077
Diesel trucks	0.961	0.754	0.605	0.497	0.416	0.357	0.313	0.280	0.257	0.240	0.230	0.225	0.225	0.230	0.080
Carbon Monoxide															
Autos	2.607	2.296	2.048	1.847	1.681	1.545	1.431	1.338	1.266	1.213	1.182	1.179	1.215	1.295	0.217
Gas trucks	5.652	4.460	3.675	3.132	2.743	2.459	2.247	2.092	1.985	1.925	1.913	1.960	2.090	2.278	0.471
Diesel trucks	4.589	3.164	2.283	1.725	1.363	1.128	0.976	0.884	0.838	0.832	0.864	0.939	1.068	1.271	0.382
Oxides of Nitrogen															
Autos	0.206	0.178	0.156	0.141	0.129	0.121	0.116	0.113	0.113	0.114	0.117	0.124	0.134	0.135	0.017
Gas trucks	0.463	0.414	0.381	0.357	0.341	0.332	0.327	0.327	0.330	0.339	0.351	0.368	0.391	0.396	0.039
Diesel trucks	4.589	3.164	2.283	1.725	1.363	1.128	0.976	0.884	0.838	0.832	0.864	0.939	1.068	1.271	0.382

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.39 FREQ 2020 Emission Rates at 75° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2020 Annual - 85 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	0.467	0.315	0.223	0.167	0.131	0.108	0.094	0.086	0.083	0.084	0.089	0.100	0.118	0.130	0.039
Gas trucks	0.988	0.657	0.459	0.335	0.257	0.207	0.173	0.153	0.141	0.137	0.139	0.148	0.165	0.168	0.082
Diesel trucks	0.961	0.754	0.605	0.497	0.416	0.357	0.313	0.280	0.257	0.240	0.230	0.225	0.225	0.230	0.080
Carbon Monoxide															
Autos	3.022	2.663	2.376	2.143	1.951	1.792	1.660	1.553	1.468	1.406	1.371	1.366	1.408	1.499	0.252
Gas trucks	6.192	4.932	4.094	3.509	3.086	2.772	2.536	2.362	2.239	2.167	2.147	2.190	2.320	2.509	0.516
Diesel trucks	4.589	3.164	2.283	1.725	1.363	1.128	0.976	0.884	0.838	0.832	0.864	0.939	1.068	1.271	0.382
Oxides of Nitrogen															
Autos	0.194	0.167	0.147	0.132	0.121	0.114	0.109	0.106	0.105	0.107	0.110	0.116	0.126	0.127	0.016
Gas trucks	0.432	0.386	0.354	0.332	0.317	0.308	0.304	0.304	0.306	0.314	0.325	0.341	0.363	0.367	0.036
Diesel trucks	4.589	3.164	2.283	1.725	1.363	1.128	0.976	0.884	0.838	0.832	0.864	0.939	1.068	1.271	0.382

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.40 FREQ 2020 Emission Rates at 85° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2020 Annual - 95 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	0.519	0.349	0.247	0.185	0.145	0.120	0.104	0.095	0.091	0.092	0.098	0.110	0.130	0.142	0.043
Gas trucks	1.072	0.714	0.499	0.366	0.281	0.226	0.190	0.168	0.156	0.152	0.154	0.165	0.185	0.187	0.089
Diesel trucks	0.961	0.754	0.605	0.497	0.416	0.357	0.313	0.280	0.257	0.240	0.230	0.225	0.225	0.230	0.080
Carbon Monoxide															
Autos	3.575	3.148	2.809	2.532	2.305	2.117	1.962	1.835	1.735	1.662	1.619	1.615	1.664	1.768	0.298
Gas trucks	6.922	5.567	4.655	4.012	3.542	3.189	2.922	2.723	2.579	2.492	2.463	2.505	2.642	2.831	0.577
Diesel trucks	4.589	3.164	2.283	1.725	1.363	1.128	0.976	0.884	0.838	0.832	0.864	0.939	1.068	1.271	0.382
Oxides of Nitrogen															
Autos	0.188	0.162	0.143	0.129	0.118	0.110	0.106	0.103	0.102	0.104	0.107	0.113	0.121	0.123	0.016
Gas trucks	0.411	0.366	0.335	0.313	0.297	0.288	0.284	0.282	0.286	0.292	0.302	0.317	0.338	0.342	0.034
Diesel trucks	4.589	3.164	2.283	1.725	1.363	1.128	0.976	0.884	0.838	0.832	0.864	0.939	1.068	1.271	0.382

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.41 FREQ 2020 Emission Rates at 95° Fahrenheit (grams/mile)

FREQ Emission Rate Table Based on EMFAC2002

Statewide Totals - Avg 2020 Annual - 105 Degrees (F) - 40% Humidity

Vehicle Class	5	10	15	20	25	30	35	40	45	50	55	60	65	70	grams/ minute "IDLE" *
	Grams per mile for average travel speeds (mph) of specific pollutant														
Total Hydrocarbons															
Autos	0.496	0.335	0.239	0.178	0.141	0.117	0.102	0.093	0.090	0.091	0.097	0.109	0.128	0.141	0.041
Gas trucks	1.050	0.701	0.491	0.360	0.278	0.224	0.190	0.168	0.156	0.152	0.154	0.165	0.186	0.188	0.087
Diesel trucks	0.961	0.754	0.605	0.497	0.416	0.357	0.313	0.280	0.257	0.240	0.230	0.225	0.225	0.230	0.080
Carbon Monoxide															
Autos	3.008	2.634	2.341	2.107	1.916	1.760	1.633	1.532	1.455	1.403	1.382	1.397	1.470	1.590	0.251
Gas trucks	6.214	4.923	4.069	3.478	3.052	2.739	2.507	2.338	2.223	2.160	2.153	2.215	2.372	2.561	0.518
Diesel trucks	4.589	3.164	2.283	1.725	1.363	1.128	0.976	0.884	0.838	0.832	0.864	0.939	1.068	1.271	0.382
Oxides of Nitrogen															
Autos	0.157	0.136	0.119	0.108	0.099	0.093	0.089	0.086	0.086	0.086	0.090	0.095	0.102	0.102	0.013
Gas trucks	0.343	0.305	0.278	0.260	0.247	0.240	0.236	0.235	0.237	0.243	0.251	0.263	0.281	0.284	0.029
Diesel trucks	4.589	3.164	2.283	1.725	1.363	1.128	0.976	0.884	0.838	0.832	0.864	0.939	1.068	1.271	0.382

* "IDLE" emission factors are calculated by converting the 5 mph emission factors (grams per mile) to grams per minute.

Table C.42 FREQ 2020 Emission Rates at 105° Fahrenheit (grams/mile)

APPENDIX D

This appendix contains an inventory of HOV freeway lanes in the following districts:

Distract Three
District Four
District Seven
District Eight
District Eleven
District Twelve

The inventory includes the route, direction, beginning and end points of the route, lane-miles, minimum occupancy required, operating period, date opened, ingress/egress information, date(s) modified, and a description of the modification.

DISTRICT THREE HOV INVENTORY										
ROUTE	DIR	LIMITS	LANE-MILES	MIN OCC	OPERATING PERIOD AM	PM	DATE OPENED	INGRESS/ EGRESS	DATE(S) MODIFIED	MODIFICATIONS
SR-99	N/B	South of Elk Grove Blvd to E St. on Rte 51	14.3	2+	6-10 AM	3-7 PM	Nov-90	Open		Opened Mack Rd Interchange to Martin Luther King Jr. Blvd
									Oct-97	Extended from Mack Road Interchange to Laguna Blvd
									Oct-98	Extended from Mack Road Interchange to South of Elk Grove Blvd
									Sep-99	Extended from Martin Luther King Jr. Blvd to E St. on Rte 51
	S/B	E St. on Rte 51 to South of Elk Grove Blvd	14.3	2+	6-10 AM	3-7 PM	Nov-90	Open		Opened Mack Rd Interchange to Martin Luther King Jr. Blvd
									Oct-97	Extended from Mack Road Interchange to Laguna Blvd
									Oct-98	Extended from Mack Road Interchange to South of Elk Grove Blvd
									Sep-99	Extended from Martin Luther King Jr. Blvd to E St. on Rte 51
US-50	W/B	El Dorado Hills Blvd to Sunrise Blvd	11.5	2+	6-10 AM	3-7 PM	Mar-02	Open		Opened Prairie City to Sunrise Blvd
									Nov-02	Extended from Prairie City to El Dorado Hills Blvd
	E/B	Sunrise Blvd to El Dorado Hills Blvd	11.5	2+	6-10 AM	3-7 PM	Jul-02	Open		Opened Prairie City to Sunrise Blvd
									Nov-02	Extended from Prairie City to El Dorado Hills Blvd
I-80	E/B	Riverside Blvd to Longview Drive	9.6	2+	6-10 AM	3-7 PM	Oct-03	Open		Opened Madison to Riverside Blvd
									Jul-04	Extended from Madison to Longview Drive
	W/B	Longview Drive to Riverside Blvd	9.6	2+	6-10 AM	3-7 PM	Jul-04	Open		Opened Riverside Ave to Longview Drive
	TOTAL EXISTING LANE-MILES		70.8							

Figure D.1 District Three HOV Inventory

DISTRICT FOUR HOV INVENTORY										
ROUTE	**DIR**	**LIMITS**	**LANE-MILES**	**MIN OCC**	**OPERATING PERIOD AM**	**PM**	**DATE OPENED**	**INGRESS/ EGRESS**	**DATE(S) MODIFIED**	**MODIFICATIONS**
ALA-80	W/B	Bay Bridge Toll Plaza	2.9	3+	5-10 AM	3-7 PM	4/17/70	Open		Opened as Bus Only
									12/8/71	Carpools Permitted
									2/2/79	Bus Only Lane 17; Op Hrs: 6:30-8:30 AM
									4/17/79	Bus Only Lane 17; Op Hrs: 6-9 AM
									10/12/81	Bus Only Lanes 18-19, 24/7; C/P Op Hrs: 6-9 AM
									2/3/89	Op Hrs: 5-10 AM
									3/1/92	Motorcycles Permitted
									10/1/95	Two-seat veh w/2 occ permitted
									4/8/97	HOV Slip Ramp opened; Op Hrs: 5-10 AM, 3-6 PM
									7/23/97	Rt 880 rt side HOV ramp opened
									2/2/98	Op Hrs 5-10 AM, 3-7 PM
									5/16/98	Rt 880 left side HOV ramp opened
ALA-80	W/B	Contra Costa Co Line to Powell St	4.2	3+	5-10 AM	3-7 PM	2/2/98	Open		HOV Flyover; Op Hrs 5 AM-7 PM
									8/3/98	Op Hrs 5-10 AM, 3-7 PM
	E/B	Port of Oakland O. C. to Contra Costa Co Line	5.3	3+	5-10 AM	3-7 PM	7/31/98	Open		Gilman St to Contra Costa County Line
									8/3/98	Op Hrs 5-10 AM, 3-7 PM
									11/20/98	Extended; Powell St to Gilman St
									11/12/03	Extended; Port of Oakland O. C. to Powell St
ALA-84	W/B	Newark Blvd to Dumbarton Bridge Toll Plaza	1.8	2+	5-10 AM	3-6 PM	10/6/82	Open		Opened with 3+ Occ Req
									1/1/92	Occ Req reduced to 2+

Figure D.2 District Four HOV Inventory (Part 1)

ROUTE	DIR	LIMITS	LANE-MILES	MIN OCC	OPERATING PERIOD AM	PM	DATE OPENED	INGRESS/ EGRESS	DATE(S) MODIFIED	MODIFICATIONS
ALA-92	W/B	Hesperian Blvd to San Mateo Bridge Toll Plaza	3	2+	5-10 AM	3-6 PM	10/23/89	Open		Opened with 3+ Occ Req; Clawiter Rd to East of Toll Plaza
									1/1/92	Occ Req reduced to 2+
									7/2/01	Extended and relocated: Hesperian Blvd to West of Toll Plaza
ALA-680	S/B	Route 84 to Route 237 Calaveras Blvd On Ramp	14	2+	5-9 AM	3-7 PM	11/26/02	Open		Opened Washington Blvd to Calaveras Blvd On Ramp
									12/5/02	Extended, Route 84 to Calaveras Blvd On Ramp
ALA-880	S/B	Marina Blvd to Mission Blvd	20.5	2+	5-9 AM	3-7 PM	9/22/91	Open		Opened, A-Street to north of Tennyson; 5-10 AM, 3-6 PM
									11/6/91	Extended; Tennyson to Industrial Pkwy
									6/26/92	Extended; Rte 238 to A-Street
									11/18/93	Extended; Industrial Pkwy to Whipple Rd
									Dec-94	Op Hrs 5-9 AM, 3-7 PM
									3/17/95	Extended; Marina Blvd to Rte 238
									6/15/98	Extended; Whipple Rd to Alvarado/Fremont Blvd
									10/23/98	Extended; Alvarado/Fremont Blvd to Mowry Ave
									12/11/98	Extended; Mowry Ave to Mission Blvd
	N/B	Mission Blvd to South of Rte 238 O. C.	16.7	2+	5-9AM	3-7 PM	9/19/91	Open		Opened; north of Tennyson to A-Street; 5-10 AM, 3-6 PM
									11/8/91	Extended; Industrial Pkwy to Tennyson
									6/26/92	Extended; A-Street to rte 238
									12/3/93	Extended; Whipple rd to Industrial Pkwy
									Dec-94	Op Hrs 5-9 AM, 3-7 PM
									9/23/96	Shortened; Whipple Rd to one mile south of Rte 238
									6/15/98	Extended; Alvarado/Fremont Blvd to Whipple rd
									10/30/98	Extended; Mowry Ave. to Alvarado/Fremont Blvd
									11/30/98	Extended; Mission Blvd (Rte 262) to Mowry Ave.

Figure D.2 District Four HOV Inventory (Part 2)

ROUTE	DIR	LIMITS	LANE-MILES	MIN OCC	OPERATING PERIOD AM	PM	DATE OPENED	INGRESS/ EGRESS	DATE(S) MODIFIED	MODIFICATIONS
ALA-880	N/B	NB West Grand Ave to EB Rte 880 HOV Lane	1.1	3+	5-10 AM	3-7 PM	11/12/03	Open		Two-seat veh w/2 occ permitted
ALA-880	N/B	16th St to SFOBB Toll Plaza	1.2	3+	5-10 AM	3-7 PM	5/16/98	Open		Two-seat veh w/2 occ permitted
CC-04	W/B	West of Railroad Ave to Port Chicago Highway	6.5	2+	6-9 AM		5/1/00	Open		Opened, Bay Point to Port Chicago Highway
									5/5/00	Extended; Bailey road to Port Chicago Highway
									7/23/01	Extended; West of Railroad Ave to Port Chicago Highway
	E/B	Port Chicago Hwy to west of Railroad Ave	7	2+		3-7 PM	8/6/01	Open		
CC-80	W/B	Rte 4 to Alameda County Line	9.7	3+	5-10 AM	3-7 PM	3/5/97	Open		Opened, Pinole Valley Rd to Cutting St; 5-10 AM
									4/18/97	Two-seat veh w/2 occ permitted
									5/3/97	Extended; Cutting Blvd to Central Ave
									9/20/97	Extended; Route 4 to Pinole Valley Rd
									2/2/98	Extended; Central Ave to Alameda Co. Line; 5 am-7 PM
									8/3/98	Op Hrs: 5-10 AM, 3-7 PM
	E/B	Alameda County Line to Rte 4	9.9	3+	5-10 AM	3-7 PM	2/12/97	Open		Opened, San Pablo Dam Rd to Pinole Valley Rd; 3-7 PM
									2/13/97	Extended; Cutting Blvd to San Pablo Dam Rd
									4/18/97	Two-seat veh w/2 occ permitted
									5/3/97	Extended; Central Ave to Cutting Blvd
									8/30/97	Extended; Pinole Valley Rd to Route 4
									2/2/98	Op Hrs: 5 AM-7 PM
									8/3/98	Extended; Alameda Co Line to Central Ave; 5-10 AM, 3-7 PM

Figure D.2 District Four HOV Inventory (Part 3)

ROUTE	DIR	LIMITS	LANE-MILES	MIN OCC	OPERATING PERIOD AM	PM	DATE OPENED	INGRESS/ EGRESS	DATE(S) MODIFIED	MODIFICATIONS
CC-680	S/B	Livonra Rd to Alcosta Blvd	11.9	2+	6-9 AM	3-6 PM	10/3/94	Open		Opened, Alcosta Blvd to Stone Valley Rd
									2/6/95	Extended; Alcosta Blvd to Livonra Rd on-ramp
	N/B	Alcosta Blvd to Livorna Rd	12.9	2+	6-9 AM	3-6 PM	10/3/94	Open		Opened, Stone Valley Rd to Alcosta Blvd on-ramp
									2/6/95	Extended; Livorna Rd on-ramp to Alcosta Blvd
									5/5/99	Shortened; Livorna Rd to north of Alcosta Blvd on-ramp
MRN-101	S/B	Greenbrae ped o/c to Strawberry ped o/c	3.7	2+	6:30-8:30 AM		12/23/74	Open		Opened; Buses Only
									6/16/76	Carpools Permitted; Occ Req 3+
									10/1/88	Occ Req reduced to 2+
									9/23/90	Motorcycles Permitted
									7/13/98	Hours Extended; 5-9 AM
									12/14/98	Extended Hours Cancelled
	N/B	S/O Richardson Bay Bridge to Corte Madera	3.5	2+		4:30-7 PM	12/20/74	Open		Opened; Buses Only
									6/15/76	Carpools Permitted; Occ Req 3+
									10/1/88	Occ Req reduced to 2+
									9/23/90	Motorcycles Permitted
									7/13/98	Hours Extended; 3-7 PM
									12/14/98	Extended Hours Cancelled
	S/B	Rte 37 to San Pedro Rd	6.1	2+	6:30-8:30 AM		7/24/87	Open		Opened; Marinwood to North San Pedro Rd; Occ Req 3+
									10/1/88	Occ Req reduced to 2+
									9/23/90	Motorcycles Permitted
									2/8/91	Extended; Marinwood to Rte 37
									7/13/98	Hours Extended; 5-9 AM
									12/14/98	Extended Hours Cancelled

Figure D.2 District Four HOV Inventory (Part 4)

ROUTE	DIR	LIMITS	LANE-MILES	MIN OCC	OPERATING PERIOD AM	PM	DATE OPENED	INGRESS/ EGRESS	DATE(S) MODIFIED	MODIFICATIONS
	N/B	San Pedro Rd to Rte 37	6.1	2+		4:30-7 PM	8/12/86	Open		Opened; North San Pedro Rd to Marinwood; Occ Req 3+
									10/1/88	Occ Req reduced to 2+
									9/23/90	Motorcycles Permitted
									2/21/91	Extended; Marinwood to Rte 37
									7/13/98	Hours Extended; 3-7 PM
									12/14/98	Extended Hours Cancelled
SCL-85	S/B	Rte 101(Mt View) to Bernal Rd	23.3	2+	5-9 AM	3-7 PM	4/25/90	Open		Opened; Rte 237 to Rte 280
									8/12/94	New Section: Almaden Expwy to Bernal Rd
									10/19/94	Extended; Rte 280 to Almaden Expwy
									11/13/98	Extended; Rte 101 (Mt View) to Rte 237
	N/B	Rte 101(So. San Jose) to Rte 101 (Mt View)	23.8	2+	5-9 AM	3-7 PM	2/22/90	Open		Opened; Rte 280 to Rte 237
									8/12/94	New Section: Rte 101 (So. San Jose) to Almaden Expwy
									10/19/94	Extended; Almaden Expwy to Rte 280
									11/6/98	Extended; Rte 237 to Rte 101 (Mt View)
SCL-101	S/B	San Mateo Co. Line to Cochrane Rd	34.8	2+	5-9 AM	3-7 PM	11/8/86	Open		Opened; Lawrence Expwy to De La Cruz Blvd
									8/8/88	Extended; Ellis St to Lawrence Expwy
									10/10/88	Extended; N. Rengstorff Ave to Ellis St
									12/12/88	Extended; San Mateo Co. Line to N. Rengstorff Ave
									6/15/90	New Section; Rte 101/280/680 I/C to Bernal Rd
									1/29/93	Extended; Rte 880 to Rte 101/280/680 I/C
									4/5/93	Extended; De La Cruz Blvd to Rte 880
									3/19/03	Extended; Bernal Rd to Cochrane Rd

Figure D.2 District Four HOV Inventory (Part 5)

ROUTE	DIR	LIMITS	LANE-MILES	MIN OCC	OPERATING PERIOD AM	PM	DATE OPENED	INGRESS/ EGRESS	DATE(S) MODIFIED	MODIFICATIONS
	N/B	Cochrane Rd to San Mateo Co. Line	34	2+	5-9 AM	3-7 PM	11/7/86	Open		Opened; Guadalupe Pkwy to Great America Pkwy
									10/10/88	Extended; Great America Pkwy to N. Rengstorff Ave
									12/12/88	Extended; N. Rengstorff Ave to San Mateo Co. Line
									6/7/90	New Section; Bernal Rd to Rte 101/280/680 I/C
									2/1/93	Extended; Rte 101/280/680 I/C to Old Oakland Rd
									4/5/93	Extended; Old Oakland Rd to Guadalupe Pkwy
									3/19/03	Extended; Cochrane Rd to Bernal Rd
SCL-237	W/B	McCarthy Blvd to Mathilda Ave	4.7	2+	5-9 AM	3-7 PM	10/31/84	Open		Opened as HOVL on Expy; Rte 880 to Lawrence Expwy; 5-9 AM
									Dec-91	Extended; Lawrence Expwy to Mathilda Ave
									5/1/95	Rte 237 Upgraded to fwy; Hrs 5-9 AM, 3-7 PM
	E/B	Mathilda Ave to Rte 880/237 Jct	6.7	2+	5-9 AM	3-7 PM	10/31/84	Open		Opened as HOVL on Expy; Lawrence Expwy to Rte 880; 3-7 PM
									Dec-91	Extended; Mathilda Ave to Rte 880
									5/1/95	Rte 237 Upgraded to fwy; Hrs 5-9 AM, 3-7 PM
									10/2/96	Shortened; Mathilda Ave to 1.1 Miles west of Rte 880
SCL-280	S/B	Magdalena Ave to Meridian Ave	11.2	2+	5-9 AM	3-7 PM	12/1/90	Open		Opened; Magdalena Ave to north of Meridian Ave
	N/B	Leland Ave to Magdalena Ave	10.7	2+	5-9 AM	3-7 PM	11/21/90	Open		Opened; Leland Ave to Magdalena Ave
SM-101	S/B	Whipple Ave to Santa Clara Co Line	6.6	2+	5-9 AM	3-7 PM	7/18/91	Open		Opened
	N/B	Santa Clara Co Line to Whipple Ave	6.6	2+	5-9 AM	3-7 PM	7/16/91	Open		Opened

Figure D.2 District Four HOV Inventory (Part 6)

ROUTE	DIR	LIMITS	LANE-MILES	MIN OCC	OPERATING PERIOD AM	PM	DATE OPENED	INGRESS/ EGRESS	DATE(S) MODIFIED	MODIFICATIONS
SOL-80	E/B	Carquinez Bridge Toll Plaza	0.1	3+	5-10 AM	3-7 PM	7/1/91	Open		Reduced 10c toll tickets for HOVs (with 50-ticket book)
									10/1/95	HOV toll free; Two-seat veh w/2 occ permitted
SON-101	S/B	Route 12 to Wilfred Ave	4	2+	7-9 AM	3-6:30 PM	11/4/02	Open		Opened; Hrs 6:30-9:30 AM, 3-7 PM
									12/11/03	Op Hrs 7-9 AM, 3-6:30 PM
	S/B	Wilfred Ave to Route 12	4	2+	7-9 AM	3-6:30 PM	11/4/02	Open		Opened; Hrs 6:30-9:30 AM, 3-7 PM
									12/11/03	Op Hrs 7-9 AM, 3-6:30 PM
	TOTAL EXISTING LANE MILES		**318.5**							

Figure D.2 District Four HOV Inventory (Part 7)

DISTRICT SEVEN HOV INVENTORY										
ROUTE	DIR	LIMITS	LANE-MILES	MIN OCC	OPERATING PERIOD AM	PM	DATE OPENED	INGRESS/ EGRESS	DATE(S) MODIFIED	MODIFICATIONS
I-10	W/B	San Bernardino Freeway/El Monte Busway,	11	3+	5-9 AM	4-7 PM	1/1/73	4		Opened as Bus Only; Op Hrs: 24/7
		El Monte to Alameda		2+	all other	times			10/1/76	Carpools Permitted
									1/1/00	Occupancy Requirement Lowered from 3+ to 2+
									7/24/00	Occ Req restored to 3+; 5-9am and 4-7pm; 2+ other times
	E/B	San Bernardino Freeway/El Monte Busway	11	3+	5-9 AM	4-7 PM	1/1/73	4		Opened as Bus Only; Op Hrs: 24/7
		Alameda to El Monte		2+	all other	times			10/1/76	Carpools Permitted
									1/1/00	Occupancy Requirement Lowered from 3+ to 2+
									5/24/00	Occ Req restored to 3+; 5-9am and 4-7pm; 2+ other times
LA-14	S/B	Antelope Valley Freeway	29.8	2+	5-9 AM		5/5/98	12		24/7 operations; Sand Canyon to San Fernando (6.4 mi)
		Pearblossom to Route 5							9/23/99	Escondido to Sand Canyon opened (9.9 mi)
									1/1/01	Part time use introduced (5-9am SB; 3-7pm NB; Mon-Fri)
									7/29/02	Pearblossom to Escondido opened (11.2 mi)
									8/3/02	San Fernando to Route 5 opened (2.3 mi)
	N/B	Antelope Valley Freeway	29.8	2+		3-7 PM	5/5/98	10		24/7 operations; San Fernando to Sand Canyon (6.4 mi)
		Route 5 to Pearblossom							9/23/99	Sand Canyon to Escondido opened (9.9 mi)
									1/1/01	Part time use introduced (5-9am SB; 3-7pm NB; Mon-Fri)
									7/29/02	Escondido to Pearblossom opened (11.2 mi)
									8/3/02	Route 5 to San Fernando opened (2.3 mi)

Figure D.3 District Seven HOV Inventory (Part 1)

ROUTE	DIR	LIMITS	LANE-MILES	MIN OCC	OPERATING PERIOD AM	PM	DATE OPENED	INGRESS/ EGRESS	DATE(S) MODIFIED	MODIFICATIONS
LA-57	S/B	Orange Freeway LA-60 to Orange County Line	4.5	2+	24/7	24/7	8/22/97	3		Opened LA-60 to Orange County Line
	N/B	Orange County Line to LA-60	4.5	2+	24/7	24/7	8/22/97	2		Opened Orange County Line to LA-60
LA-60	W/B	Pomona Freeway San Bernardino County Line to Brea Canyon	7.5	2+	24/7	24/7	2/2/99	3		Opened San Bernardino County Line to Brea Canyon
	E/B	Brea Canyon to San Bernardino County Line	7.5	2+	24/7	24/7	2/2/99	3		Opened Brea Canyon to San Bernardino County Line
LA-91	W/B	Artesia Freeway	14.3	2+	24/7	24/7	3/11/93	4		Opened Route 605 to Route 110 (10.3 mi)
		Orange County Line to Route 110							11/1/94	Extended: Orange County Line to Route 605 (4 mi)
	E/B	Route 110 to Orange County Line	14.3	2+	24/7	24/7	6/10/85	4		Opened Route 110 to Route 605 (10.3 mi)
									11/1/94	Extended: Route 605 to Orange County Line (4 mi)
I-105	W/B	Glenn Anderson/Century Freeway Route 605 to Route 405	16	2+	24/7	24/7	10/14/93	6		Opened Route 605 to Route 405
	E/B	Route 405 to Route 605	16	2+	24/7	24/7	10/14/93	7		Opened Route 405 to Route 605
I-110	N/B	Harbor Freeway Route 91 to Adams Blvd	10.7	2+	24/7	24/7	6/26/96	3		Opened Route 91 to Adams Blvd
	S/B	Adams Blvd to Route 91	10.7	2+	24/7	24/7	6/26/96	3		Opened Adams Blvd to Route 91
LA-118	E/B	Ronald Reagan Freeway Ventura County Line to Route 5	11.4	2+	24/7	24/7	3/7/97	4		Opened Ventura County Line to Route 5
	W/B	Route 5 to Ventura County Line	11.4	2+	24/7	24/7	3/7/97	3		Opened Route 5 to Ventura County Line
LA-134	E/B	Ventura Freeway Route 101/170 to Route 5	5.1	2+	24/7	24/7	10/2/95	2		Opened, Route 101/170 to Route 5 (5.1 mi)
	W/B	Route 5 Route 101/170	5.1	2+	24/7	24/7	10/2/95	2		Opened, Route 5 Route 101/170 (5.1 mi)
	E/B	Route 5 to Route 210	7.8	2+	24/7	24/7	3/12/96	2		Opened, Route 5 to Route 2 (4.2 mi)
				2+	24/7	24/7		2	8/30/96	Extended; Route 2 to Route 210 (3.6 mi)
	W/B	Route 210 to route 5	7.8	2+	24/7	24/7	3/12/96	2		Opened, Route 2 to Route 5 (4.2 mi)
				2+	24/7	24/7		2	8/30/96	Extended; Route 210 to Route 2 (3.6 mi)

Figure D.3 District Seven HOV Inventory (Part 2)

ROUTE	DIR	LIMITS	LANE-MILES	MIN OCC	OPERATING PERIOD AM	PM	DATE OPENED	INGRESS/ EGRESS	DATE(S) MODIFIED	MODIFICATIONS
LA-170	S/B	Hollywood Freeway Route 5 to Route 101/134	6.1	2+	24/7	24/7	2/11/96	2		Opened Route 5 to Route 101/134
	N/B	Route 101/134 to Route5	6.1	2+	24/7	24/7	2/11/96	2		Opened Route 101/134 to Route5
I-210	W/B	Foothhill Freeway San Bernardino County Line to Route 134	26.8	2+	24/7	24/7	12/16/93	14		Opened, Sunflower Ave to Route 134 (18.5 mi)
									9/8/97	Extended; Foothill Blvd to Sunflower Ave (2.3 m)
									11/24/02	Extended; San Bernardino County Line to Foothill Blvd (6 mi)
	E/B	Route 134 to San Bernardino County Line	26.8	2+	24/7	24/7	12/16/93	14		Opened, Route 134 to Sunflower Ave (18.5 mi)
									9/8/97	Extended; Sunflower Ave to Foothill Blvd (2.3 m)
									11/24/02	Extended; Foothill Blvd to San Bernardino County Line (6 mi)
I-405	S/B	San Diego Freeway Interstate 105 to Orange County Line	25.6	2+	24/7	24/7	4/8/93	10		Opened, 120th Street to Route 110 (7.7 mi)
									10/2/93	Opened, Route 605 to Bellflower Blvd (2.2 mi)
									1/1/94	Extended, Century Blvd to 120th Street (2.0 mi)
									2/12/98	Extended, Route 710 to Orange Count Line (7.6 mi)
									10/8/98	Extended, Route 110 to Route 710 (6.1 mi)
	N/B	Orange County Line to Interstate 105	25.6	2+	24/7	24/7	4/8/93	10		Opened, Route 110 to 120th Street (7.7 mi)
									10/2/93	Opened, Bellflower Blvd to Route 605 (2.2 mi)
									1/1/94	Extended, 120th Street to Century Blvd (2.0 mi)
									2/12/98	Extended, Orange Count Line to Route 710 (7.6 mi)
									10/8/98	Extended, Route 710 to Route 110 (6.1 mi)
	S/B	Route 5 to Waterford	17.9	2+	24/7	24/7	10/22/96	8		Opened, Route 5 to Route 101 (10.1 mi)
									1/8/02	Extended, Route 101 to Waterford (7.8 mi)
	N/B	Route 101 to Route 5	10.1	2+	24/7	24/7	10/22/96	3		Opened, Route 101 to Route 5 (10.1 mi)

Figure D.3 District Seven HOV Inventory (Part 3)

ROUTE	DIR	LIMITS	LANE-MILES	MIN OCC	OPERATING PERIOD AM	PM	DATE OPENED	INGRESS/ EGRESS	DATE(S) MODIFIED	MODIFICATIONS
I-605	S/B	San Gabriel River Freeway	20.7	2+	24/7	24/7	4/2/97	10		Opened, Telegraph Road to South Street (7.0 mi)
		I-10 to Orange County Line							4/3/98	Extended; I-10 to Telegraph Road (9.9 mi)
									3/1/01	Extended; South Streeet to Orange County Line (3.8 mi)
	N/B	Orange County Line to I-10	20.7	2+	24/7	24/7	4/2/97	9		Opened, South Street to Telegraph Road (7.0 mi)
									4/3/98	Extended; Telegraph Road to I-10 (9.9 mi)
									3/1/01	Extended; Orange County Line to South Streeet (3.8 mi)
		TOTAL EXISTING LANE MILES	**422.6**					**169**		

Figure D.3 District Seven HOV Inventory (Part 4)

DISTRICT EIGHT HOV INVENTORY											
ROUTE	DIR	LIMITS	LANE-MILES	MIN OCC	OPERATING PERIOD AM	PM	DATE OPENED	INGRESS/ EGRESS	DATE(S) MODIFIED	MODIFICATIONS
I-10	W/B	West of I-15 to L. A. County Line	9.9	2+	24/7	24/7	Jan-00	Controlled		Opened West of I-15 to L. A. County Line
	E/B	L. A. County Line to West of I-15	9.9	2+	24/7	24/7	Jan-00	Controlled		Opened L. A. County Line to West of I-15
SR-60	W/B	Milliken Ave to L. A. County Line	10	2+	24/7	24/7	Jan-97	Controlled		Opened Milliken Ave to L. A. County Line
	E/B	L. A. County Line to Milliken Ave	10	2+	24/7	24/7	Jan-97	Controlled		Opened L. A. County Line to Milliken Ave
SR-71	N/B	Riverside County Line to LA County Line	8.3	2+	24/7	24/7	Oct-98	Controlled		Opened Riverside County Line to LA County Line
	S/B	LA County Line to Riverside County Line	8.3	2+	24/7	24/7	Jan-98	Controlled		Opened LA County Line to Riverside County Line
SR-91	W/B	Mary Street UC to Orange County Line	17.4	2+	24/7	24/7	Sep-92	Controlled		Opened, Magnolia Ave. to Main St. (4.9 mi)
				Toll					Sep-93	Extended, Main St. to Orange County Line (6.3 mi.)
									Jun-95	Extended, Mary St. to Magnolia Ave (6.2 mi)
	E/B	Orange County Line to Mary Street UC	17.4	2+	24/7	24/7	Sep-92	Controlled		Opened, Main St. to Magnolia Ave (4.9 mi)
				Toll					Sep-93	Extended, Orange County Line to Main St. (6.3 mi.)
									Aug-95	Extended, Magnolia Ave to Mary St. (6.2 mi)
	TOTAL EXISTING LANE-MILES		91.2							

Figure D.4 District Eight HOV Inventory

DISTRICT ELEVEN HOV INVENTORY										
ROUTE	DIR	LIMITS	LANE-MILES	MIN OCC	OPERATING PERIOD AM	PM	DATE OPENED	INGRESS/ EGRESS	DATE(S) MODIFIED	MODIFICATIONS
I-5	N/B	I-5/I-805 Junction to Via De La Valle	5.8	2+	24/7	24/7	09/_/00	1 in/ 1 out		24/7 operations; Sand Canyon to San Fernando (6.4 mi)
I-15	S/B	SR-56 to SR-163	7.5	2+	6-9 AM	Closed	10/_/1988	1 in/2 out		Two Reversible Lanes on Barrier Separated Roadway
										Lanes opened to toll-paying Single Occupant Vehicles
									4/3/00	Operating hours extended to 5:45 - 11 AM
	N/B	SR-163 to SR-56	7.5	2+	Closed	3-6 PM	10/_/1988	2 in/1 out		Two Reversible Lanes on Barrier Separated Roadway
										Lanes opened to toll-paying Single Occupant Vehicles
									4/3/00	Operating hours extended to 1:00 to 7:00 PM
SR-54	E/B	I-805 to West of SR-125	3.2	2+		3-7 PM	08/_/1996	Contiguous		
									01/_/01	Median barrier added
	W/B	West of SR-125 to I-805	3.2	2+	6-9 AM		08/_/1996	Contiguous		
									01/_/01	Median barrier added
SR-75	S/B	Coronado Bridge Toll Plaza	0.1	2+	24/7	24/7	07/_/1966			HOV Bypass Lane at Gate # 7 of Toll Bridge
SR-94	W/B	SR-94-to-SR-125 Connector	1	2+	24/7	24/7	1978			Ramp Meter Bypass Lane on SR-94-to-SR-125 Connector
	TOTAL EXISTING LANE MILES		**28.3**							

Figure D.5 District Eleven HOV Inventory

DISTRICT TWELVE HOV INVENTORY											
ROUTE	**DIR**	**LIMITS**	**LANE-MILES**	**MIN OCC**	**OPERATING PERIOD AM**	**PM**	**DATE OPENED**	**INGRESS/ EGRESS**	**DATE(S) MODIFIED**	**MODIFICATIONS**
I-5	N/B	SR-1 to Beach Blvd.	39.7	2+	24/7	24/7	Oct-92	Controlled		Opened Alton Parkway to Newport Ave UC (7 mi)
									May-96	Extended from Newport Ave UC to Santa Ana River (4.9 mi)
									Jul-96	Extended from El Toro Road to Alton Parkway (5.5 mi)
									Jul-96	Opened I-5/SR-1 Separation to Avery Parkway (6.1 mi)
									Oct-97	Extended from Avery Parkway to El Toro Road (6.7 mi)
									Sep-00	Extended from Santa Ana River to Broadway Street OC (4.6 mi)
									Jan-01	Extended from Broadway Street OC to Beach Blvd. (4.9 mi)
	S/B	Beach Blvd. To SR-1	39.7	2+	24/7	24/7	Oct-92	Controlled		Opened Newport Ave UC to Alton Parkway (7 mi)
									May-96	Extended from Santa Ana River to Newport Ave UC (4.9 mi)
									Jul-96	Extended from Alton Parkway to El Toro Road (5.5 mi)
									Jul-96	Opened Avery Parkway to I-5/SR-1 Separation (6.1mi)
									Oct-97	Extended from El Toro Road to Avery Parkway (6.7 mi)
									Sep-00	Extended from Broadway Street OC to Santa Ana River (4.6 mi)
									Jan-01	Extended from Beach Blvd. to Broadway Street OC (4.9 mi)
SR-55	N/B	I-405 to South of SR-91/SR-55 Separation	11.3	2+	24/7	24/7	Nov-85	Controlled		Opened I-405 to South of SR-91/SR-55 Separation
	S/B	South of SR-91/SR-55 Separation to I-405	11.3	2+	24/7	24/7	Nov-85			Opened South of SR-91/SR-55 Separation to I-405
SR-57	N/B	I-5/SR-22/SR-57 IC to LA County Line	11.7	2+	24/7	24/7	Jun-92	Controlled		Opened I-5/SR-22/SR-57 IC to Lambert Road Off-Ramp (9.9 mi)
									Aug-97	Extended: Lambert Road Off-Ramp to LA County Line (1.8 mi)
	S/B	LA County Line to I-5/SR-22/SR-57 IC	11.7	2+	24/7	24/7	Jun-92	Controlled		Opened Lambert Road Off-ramp to I-5/SR-22/SR-57 IC (9.9 mi)
									Aug-97	Extended: LA County Line to Lambert Road Off-Ramp (1.8 mi)

Figure D.6 District Twelve HOV Inventory (Part 1)

ROUTE	DIR	LIMITS	LANE-MILES	MIN OCC	OPERATING PERIOD AM	PM	DATE OPENED	INGRESS/ EGRESS	DATE(S) MODIFIED	MODIFICTIONS
SR-91	W/B	LA County Line to Riverside County Line	33.45	2+	24/7	24/7	Aug-95	Controlled		Opened, East of SR-91/SR-57 Sep. to Riverdale Ave. OC (2.5 mi)
				Toll					Dec-95	Opened, Riverdale Ave OC to Riverside Co. Line (20.2 mi: Toll+ HOV)
									Jun-99	Opened, LA County Line to Stanton Ave UC (2.8 mi)
									Feb-00	Extended, Gilbert St. UC to East of SR-91/SR-57 (5.8 mi)
									Dec-00	Extended, Stanton Ave UC to Gilbert St UC (2.65 mi)
	E/B	Riverside County Line to LA County Line	33.45	2+	24/7	24/7	Aug-95	Controlled		Opened, Riverdale Ave OC to East of SR-91/SR-57 Sep. (2.5 mi)
				Toll					Dec-95	Opened, Riverside Co. Line to Riverdale Ave OC (20.2 mi: Toll+ HOV)
									Jun-99	Opened, Stanton Ave UC to LA County Line (2.8 mi)
									Feb-00	Extended, East of SR-91/SR-57 to Gilbert St. UC (5.8 mi)
									Dec-00	Extended, Gilbert St UC to Stanton Ave UC (2.65 mi)
I-405	N/B	San Diego Freeway: I-5 to I-605	24.3	2+	24/7	24/7	Jan-89	Controlled		Opened, SR-73 to I-405/I-605 Separation (13.7 mi)
									May-91	Extended, I-5 to SR-73 (8.8 mi)
									Jul-96	Extended, I-5/I-405 Separation to N. of Irvine Center Dr. (1.3 mi)
									Feb-98	Extended, I-405/I-605 Separation to Atherton St. UC (0.5 mi)
	S/B	San Diego Freeway: I-605 to I-5	24.3	2+	24/7	24/7	Jan-89	Controlled		Opened, I-405/I-605 Separation to SR-73 (13.7 mi)
									May-91	Extended, SR-73 to I-5 (8.8 mi)
									Jul-96	Extended, N. of Irvine Center Dr. to I-5/I-405 Separation (1.3 mi)
									Feb-98	Extended, Atherton St. UC to I-405/I-605 Separation (0.5 mi)
	TOTAL EXISTING LANE-MILES		240.9							

Figure D.6 District Twelve HOV Inventory (Part 2)