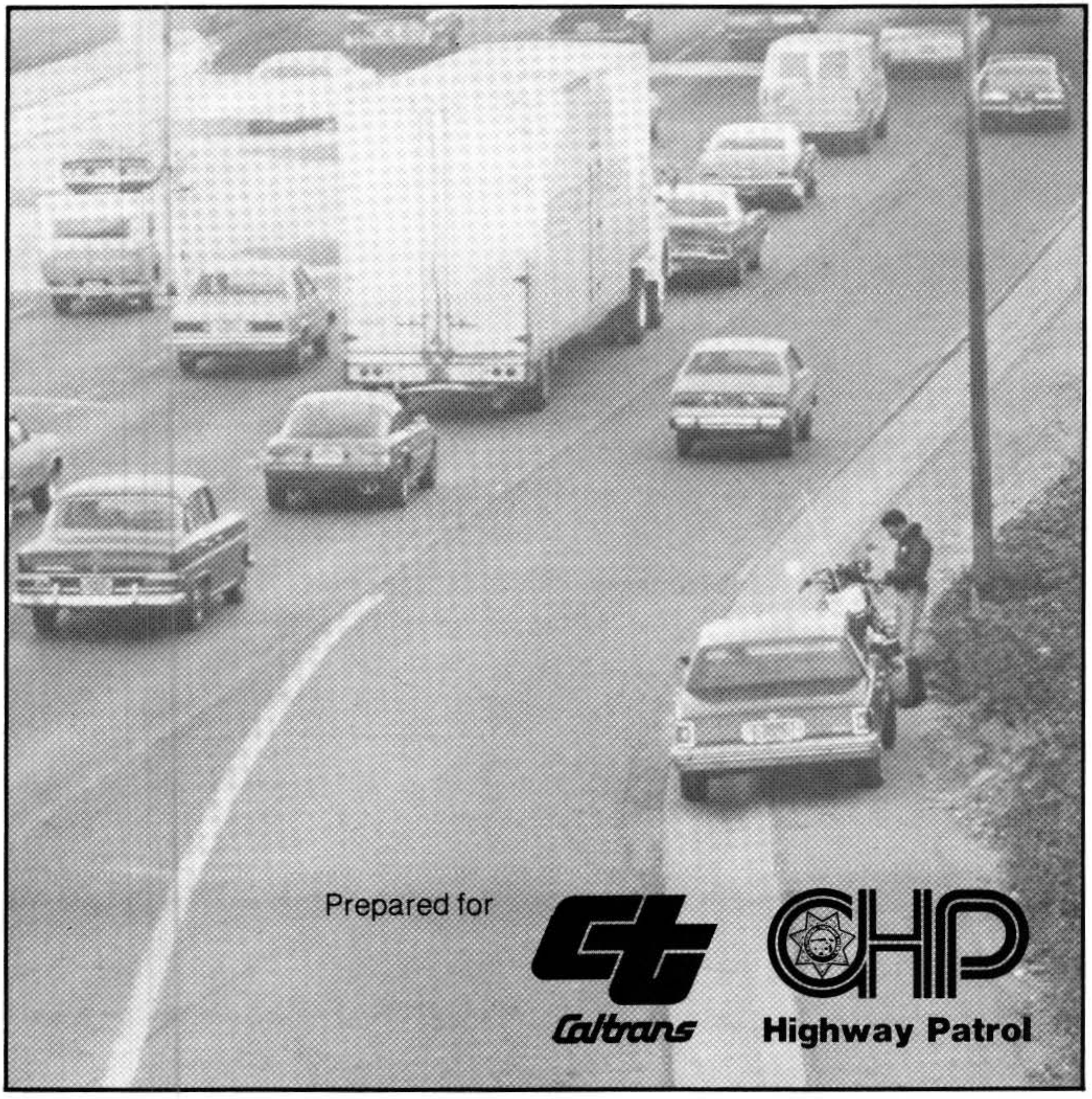
US Department
of Transportation

October 1981

TSM Project Violation Rates:
Final Report



Prepared for

Caltrans

Highway Patrol

TSM PROJECT VIOLATION RATES

Final Report

Prepared by Systan Inc. for
State of California Department of Transportation
and Department of the California Highway Patrol

Caltrans

Highway Patrol

FOREWORD

The fiscal constraints of the past decade and the accompanying pressure to exercise greater responsibility in the expenditure of public dollars have resulted in significant changes in our approach to solving transportation problems. Large capital outlays for new facilities are no longer commonplace. Instead, efforts are being made to maximize the use of existing facilities through a variety of transportation systems management (TSM) strategies. The success of these strategies is largely dependent upon public compliance with TSM regulations. Control of TSM violation rates, therefore, has become one of the many challenges confronting public agencies responsible for operating the transportation system. Unfortunately, very little information is available regarding TSM violation rates.

This publication is the final report on a two-year joint effort between the California Highway Patrol, the California Department of Transportation and Systan, Inc. The TSM Violation Rate Study was designed to quantify the effect of various enforcement, engineering and public education strategies on TSM violation rates. We feel the project has been very successful and should prove invaluable in the design and operation of TSM facilities nationwide.

G. B. CRAIG, Commissioner
California Highway Patrol

PREFACE AND ACKNOWLEDGMENTS

This is the final report on a twenty-month study designed to measure and evaluate the effect of different enforcement levels and strategies, engineering features, and public education programs on violation rates for various Transportation System Management (TSM) projects, particularly those involving preferential treatment for high-occupancy vehicles.

The report has been prepared in the Los Altos, California offices of SYSTAN, Inc. under Contract No. C-435-79/80 with the Department of the California Highway Patrol (CHP). The project was jointly sponsored by the California Department of Transportation (CALTRANS) with funding provided by the Office of Traffic Safety of the California Department of Transportation. Chief J.E. Smith, Commander of the Highway Patrol's Planning and Analysis Division, served as project director, and Captain Maury Hannigan of the Long-Range Planning Section of that Division was the CHP's project manager.

A steering committee comprised of representatives from the CHP, CALTRANS, the Office of Traffic Safety, and the public at large was responsible for overall project guidance and for approving the products of major project tasks. In addition to Chief Smith, other members of the steering committee were: Chief William Oliver of the CHP's Sacramento Office; Mr. David Roper of CALTRANS District 07; Mr. William Schaeffer of CALTRANS' Sacramento Office; Mr. Thornton Piersall of the League of California Cities; Mr. David Grayson of the Automobile Club of Southern California; and Mr. G. Van Oldenbeek of the Office of Traffic Safety.

SYSTAN's project manager and principal investigator was Dr. John W. Billheimer. Other SYSTAN staff members assigned to the study included: Ms. Juliet McNally, who was responsible for data coordination, survey analyses, and the accident investigation; Mr. Robert Trexler, who supervised statistical analyses and the investigation of mainline HOV lanes; Mr. Andrew Canfield, who supervised data processing activities; and Ms. GiGi Gillson and Ms. Leslie Pera, who organized and prepared the final report. Mr. Jesse Glazer of Crain and Associates assisted with the study of the San Bernardino Busway. Professor Adolf D. May, Mr. Walter Okitsu, and Mr. Tsutomu Imada of the University of California's Institute of Transportation Studies used their computer models of freeway operations to help provide insights into the impact of violations on traffic flow.

Liaison with CALTRANS and CHP field personnel throughout the state was accomplished through a coordinating committee chaired by Sgt. Tom Boswell of the CHP. Coordinating committee representatives in each major metropolitan area were:

AREA	CHP Member	CALTRANS Member
San Francisco	Sgt. Hal Koehncke	Mr. Len Newman
Los Angeles	Lt. William Russell	Mr. Gary Bork
San Diego	Lt. Lee Denno	Mr. Stuart Harvey

The study has profited greatly from the assistance of many other individuals within CALTRANS and the CHP. Robert Goodell and Arnold Mahelona of CALTRANS District 07 supervised the collection of operational data and provided a wealth of insights regarding TSM projects in and around Los Angeles. James McCrank of CALTRANS District 04 provided a similar service in San Francisco, as did Lawrence Wherry of CALTRANS District 11 in San Diego. Data and insights regarding the operation of the San Bernardino Busway were supplied by Hank Harada and Hank Brockmann of CALTRANS District 07. Sgt. Mike Maples of the CHP's Sacramento Headquarters oversaw the collection and coordination of enforcement records and acted as the project's liaison officer, while Officer John Novak helped to provide liaison with the Command Areas within the CHP's Southern Division. Other individuals contributing their time to the various project committees included Chief Harold Jones, Chief W. Haas, Chief Harry Adair, Captain Keith Newman, Lieutenant William Dwyer, and Lieutenant Steve Wilkins of the California Highway Patrol; Mr. James Borden and Mr. Richard Ginsberg of CALTRANS; and Mr. Arnie Trotter of the Office of Traffic Safety. Mr. John Keller of the CHP's Long Range Planning Section monitored the study design and offered many valuable suggestions throughout the investigation.

This Report has been printed in two Volumes:

Volume I contains the Executive Summary
Volume II contains the Technical Report

CONTENTS

LIST OF EXHIBITS

1. BACKGROUND

1.1 THE PROBLEM

In recent years, several different Transportation System Management (TSM) strategies have been introduced on California freeways. These strategies have included ramp metering, preferential freeway lanes for high-occupancy vehicles (HOVs), and bypass lanes for HOVs at metered ramps. A number of factors have arisen to frustrate efforts to enforce the traffic laws accompanying these strategies; these include personnel constraints, enforcement priorities, public hostility toward certain preferential treatment projects (particularly the controversial Santa Monica Freeway Diamond Lane demonstration), confusion over new traffic concepts, and physical limitations imposed by the geometry and engineering features of specific projects. As a consequence, violation rates have increased on certain TSM projects, and are likely to continue to increase as more and more projects are introduced and enforcement manpower is stretched thinner and thinner.

1.2 STUDY OBJECTIVES

Adequate control of violation rates on preferential HOV facilities and other TSM projects requires an effective mixture of enforcement, engineering design changes, and public education. Although past operating experience with TSM strategies has given the California State Department of Transportation (CALTRANS) and the California Highway Patrol (CHP) a number of insights into the types of enforcement strategies, engineering changes, and education programs that might prove efficacious, this experience has not been documented with the quantitative precision necessary to identify the appropriate levels and mixture of these factors needed to obtain adequate motorist compliance. The purpose of this study has been to provide a detailed, quantitative, and objective assessment of the effect of different enforcement options, engineering features and educational programs on violation rates for various TSM freeway strategies, and to trace the resulting impact of these violation rates on safety, freeway performance and public attitudes.

1.3 HISTORICAL VIOLATION RATES

As a first step in accomplishing the study objectives, existing California TSM projects were surveyed, future plans for such projects were documented, and current statistics were assembled describing violation rates, enforcement levels, and operating performance on current and past TSM projects in California. Exhibit 1.1 summarizes these statistics for the Spring of 1980, prior to the introduction of any special enforcement programs. Exhibits 1.2 through 1.5 provide additional insights into these statistics for the four classes of TSM project of primary interest in this study:

- Mainline HOV Lanes (Exhibit 1.2);
- Ramp Meter Bypass Lanes (Exhibit 1.3);
- Special Bridge Lanes (Exhibit 1.4); and
- Metered Freeway Ramps (Exhibit 1.5).

Exhibit 1.1

TSM PROJECT VIOLATION RATES
and
ROUTINE (HISTORICAL) ENFORCEMENT LEVELS

(Base Period Data – Spring, 1980)

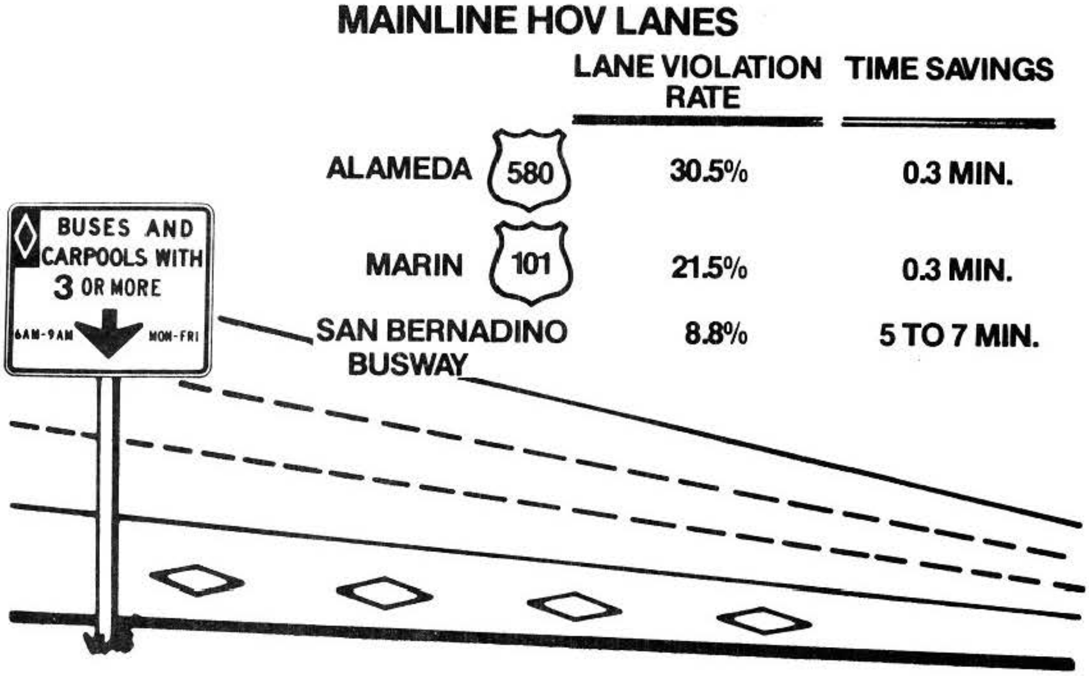
PROJECT	VIOLATION DATA		ENFORCEMENT DATA		OPERATING DATA
	Lane Violation Rate	Ramp or FWY Violation Rate	Past Citation Rates	Apprehension Rate	Average HOV Time Savings (Mins During Peak Hour)
MAINLINE HOV LANES					
Non-Separated Lanes:					
Marin 101	21.5%		11.6/day	2.6%	Negligible (average under 20 seconds)
Santa Monica*	15.1%	1.0%	55/day		5-6
Separated Lanes:					
Alameda I-580	30.5%		2.5/day	0.8%	Negligible (average under 20 seconds)
San Bernardino	8.8%		10.8/day	3.3%	5-7
METERED RAMPS					
Without Bypass Lanes:	3.8%**	3.8%**	N/A	N/A	N/A
With Bypass Lanes:					
Los Angeles	37.7%	12.8%	.27/ramp/day	0.18%	1.3
San Diego	19.5%	3.0%	.07/ramp/day	0.24%	0.4
EXCLUSIVE HOV BRIDGE LANE					
S.F.-Oakland Bay Bridge	5.4%	0.7%	2.4/day	1.1%	4-5

*Project Discontinued

**Meter Violation Rate

Exhibit 1.2

BASELINE LEVELS: MAINLINE HOV LANES



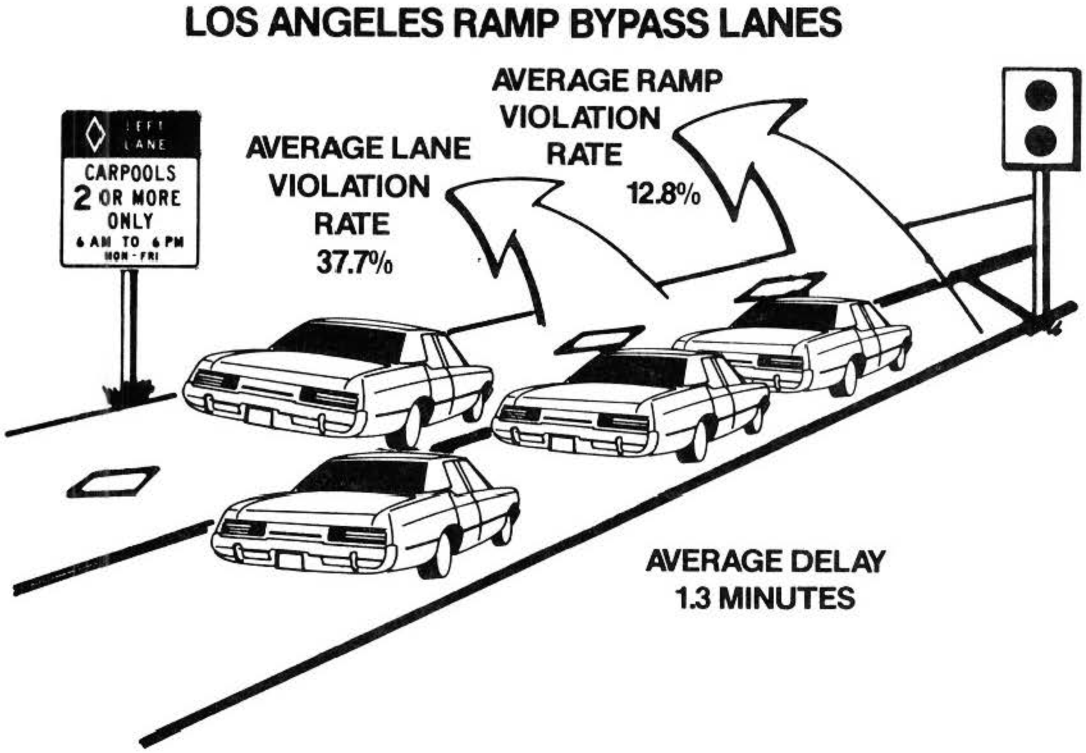
MAINLINE HOV LANES

	LANE VIOLATION RATE	TIME SAVINGS
ALAMEDA 580	30.5%	0.3 MIN.
MARIN 101	21.5%	0.3 MIN.
SAN BERNADINO BUSWAY	8.8%	5 TO 7 MIN.

The percentage of vehicles using California mainline HOV lanes illegally during the spring of 1980 ranged from 8.8% on the San Bernardino Busway to 30.5% on the controversial Alameda I-580 diamond lanes. Occupancy violations on the shoulder-separated right-of-way of the San Bernardino Busway averaged 7.3% of all vehicles in the lane during the morning peak and 10.5% of all vehicles in the afternoon. These violation rates were lower still (estimated at 3% to 4%) on the portion of the Busway where a physical barrier makes lane-switching impossible. While violation rates on the San Bernardino Busway and Alameda 580 had not increased appreciably over prior measurements, the 21.5% violation rates recorded on Marin 101 represented an increase over the violation rates of 5% to 15% reported roughly one year earlier (Reference 1).

Exhibit 1.3

BASELINE LEVELS: RAMP METER BYPASS LANES



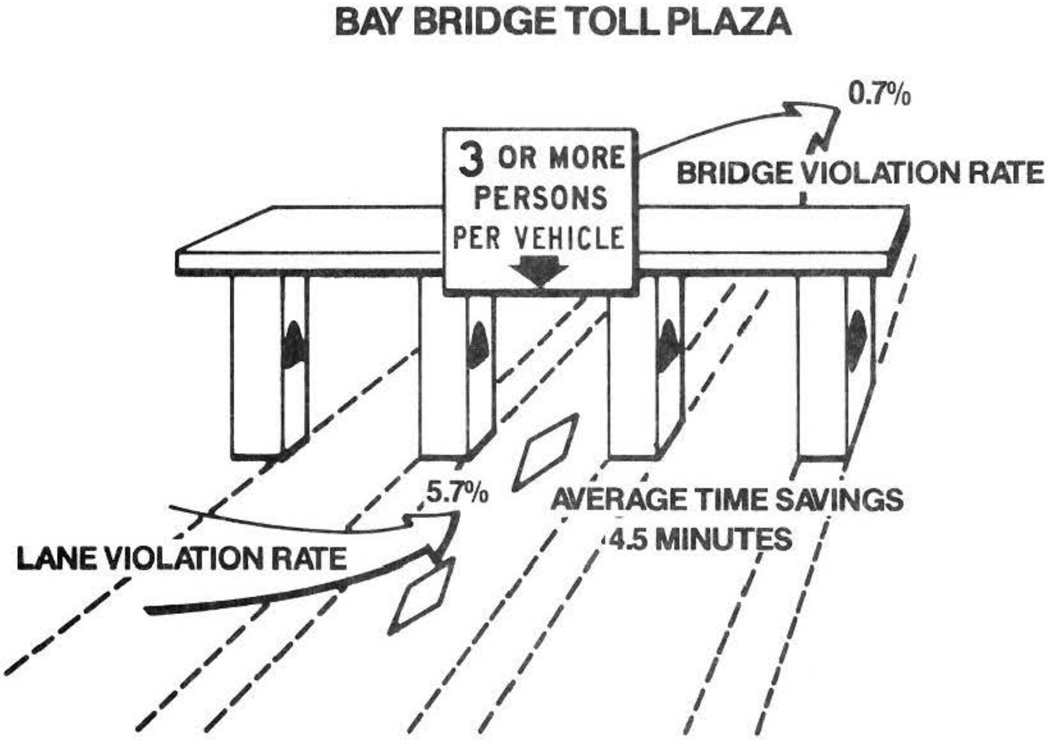
Prior to the start of this study the average lane violation rate for a sampling of thirty-nine metered ramps with HOV bypass lanes in the Los Angeles area was 37.7%, appreciably higher than the comparable violation rate on any mainline HOV project in California. This corresponded to an average ramp violation rate of 12.8%, a rate which had been increasing at two percentage points per year on individual ramps. As a result of this increase, bypass lanes that had been operational for several years had significantly higher ramp violation rates than newly-opened lanes. In Los Angeles, the relative number of vehicles using bypass lanes illegally ranged from 13.4% on one heavily-enforced ramp (Colorado Boulevard on LA 5) to over two-thirds of all vehicles in the bypass lane on the Western Avenue ramp to the westbound Santa Monica freeway.

HOV lane violation rates were found to be considerably lower (averaging 19.5% on a sampling of seven HOV bypass lanes) in San Diego, where the peak traffic periods are shorter, meters are traffic-responsive, and the HOV lanes themselves are meter-controlled.

In the past, the CHP had generally applied a policy of routine enforcement to bypass lanes, using available personnel to enforce the lane restrictions in addition to regular patrol duties. With over 130 bypass lanes in the Los Angeles area alone, however, the supply of bypass lanes in some CHP command areas actually outnumbered the supply of officers available for all patrol duties during the peak traffic periods. As a result, a survey of seven command areas in Los Angeles area and two in San Diego showed that the average number of citations issued per bypass lane was slightly over one per week.

Exhibit 1.4

BASELINE LEVELS: BAY BRIDGE TOLL PLAZA

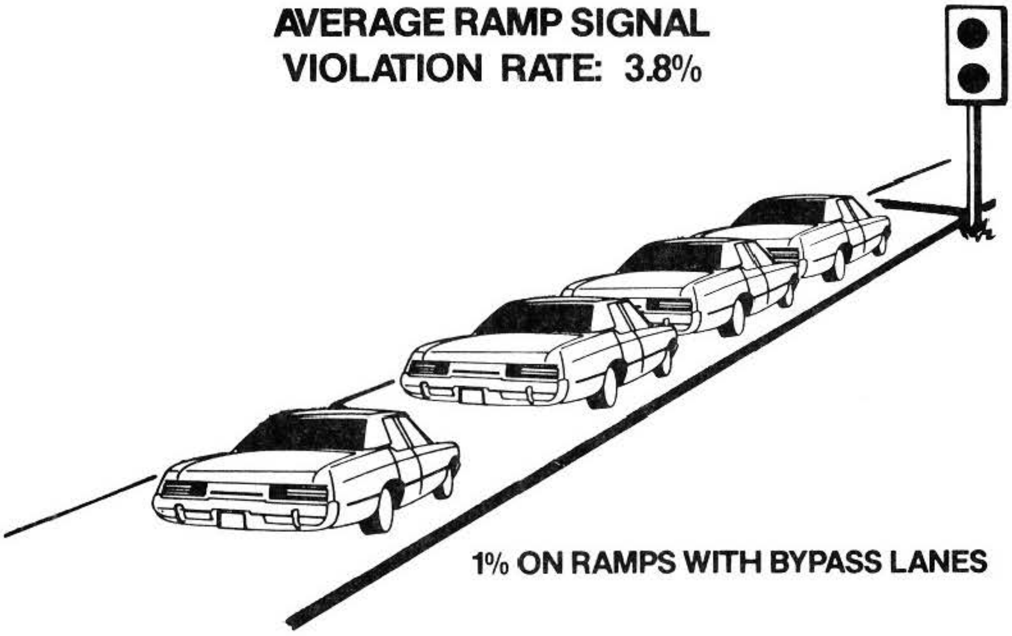


Two lanes of the seventeen westbound lanes approaching the toll plaza of the San Francisco/Oakland Bay Bridge have been reserved for the exclusive use of carpools with three or more occupants, while a third lane is reserved for buses. These lanes provide free passage through the toll booth, and preferential treatment at the meters controlling access to the bridge itself, thereby saving carpoolers and buses from 4 to 5 minutes in their morning commute, as well as the 75-cent bridge toll.

Although these savings are consistently higher than those available to drivers on most other TSM projects in California, the 5.4% violation rate on the Bay Bridge was the lowest baseline level recorded on any TSM project. The CHP regularly deploys five or six officers on the Bay Bridge during the peak morning commute hours, and in the past special enforcement teams of three to four additional officers have been assigned to bridge enforcement duty about twice a month to keep violation rates from rising.

Exhibit 1.5

BASELINE LEVELS: RAMP METER VIOLATION RATES



The number of drivers ignoring meter restrictions by "running" the red light, is relatively low, and is not considered to be a major problem by either CALTRANS or the CHP, particularly because such violations tend to occur when traffic volumes are low and ramp queues are short or non-existent. In Los Angeles, the level of meter violations was significantly higher on ramps without bypass lanes than on ramps with such lanes (3.8% versus 1.0% of all vehicles on the ramp), as the bypass lane itself provides a convenient pathway for those potential violators who might otherwise simply run the red light.

1.4 EVALUATION OVERVIEW

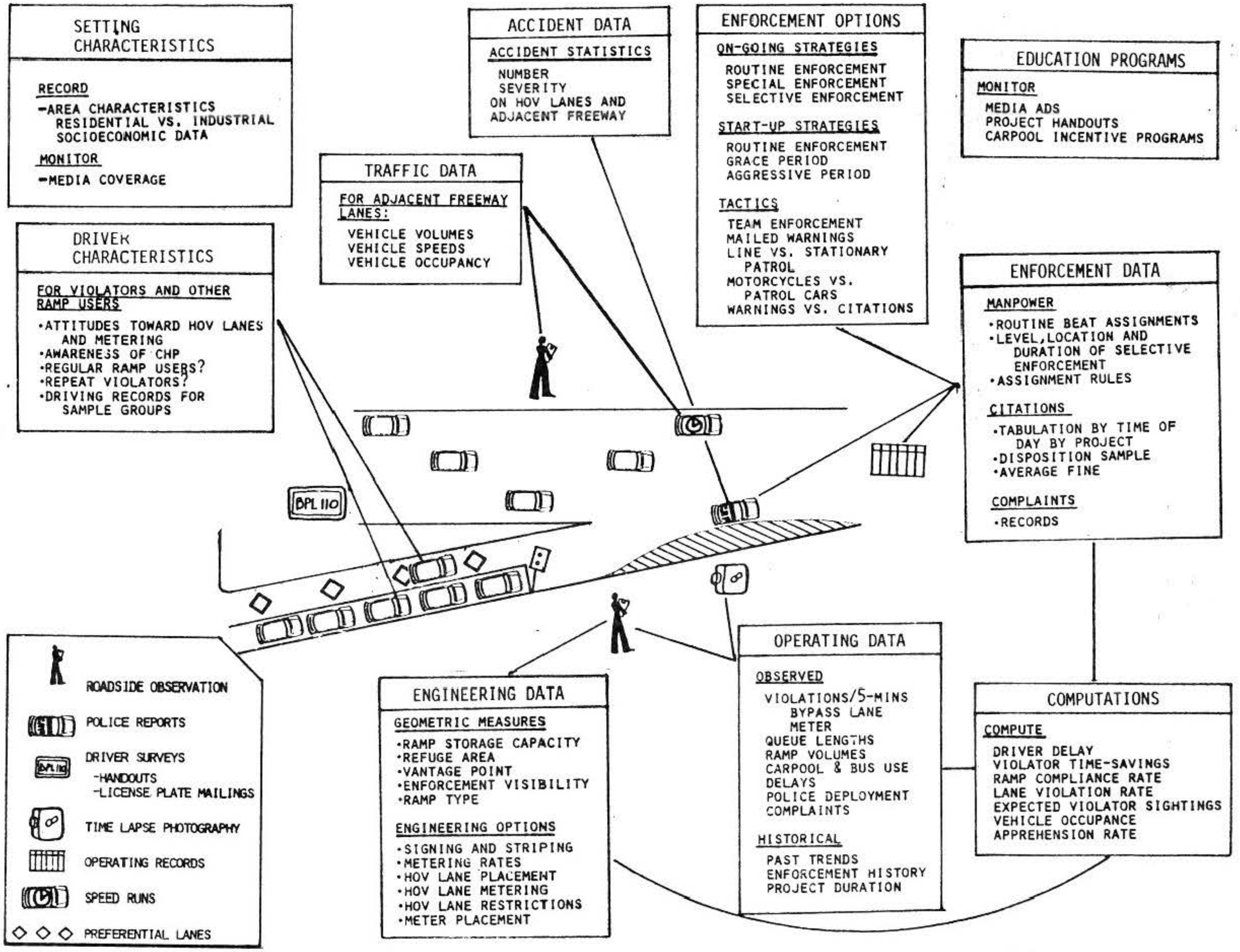
Before undertaking the current evaluation, SYSTAN, Inc. developed a detailed Study Design (Reference 3) that provided a structured statistical framework relating quantitative measures of effectiveness to established objectives and stipulating detailed procedures for assessing whether these objectives had been satisfied. Detailed contents of the Study Design included summaries of existing and planned TSM projects; tableaus outlining procedures for data collection and analysis; specifications for the statistical tests to be used in validating the analysis; and checklists to assist the agencies responsible for field data collection.

Exhibit 1.6 presents a graphic overview of the evaluation plan proposed in the Study Design. This exhibit shows each of the data categories sought, itemizes the major data elements within each category, and depicts the data collection instruments employed in monitoring the impacts of different enforcement, engineering and education options on ramp bypass lane violations. Similar data categories, measures, and collection instruments were used in assessing violation rates on mainline HOV lanes, exclusive toll plaza lanes, and other TSM projects.

1.4.1 Projects to be Evaluated

Mainline HOV Lanes. In the case of mainline HOV lanes, the different engineering options evaluated were limited to the major projects currently in place on California freeways. These projects are summarized below.

Exhibit 1.6 – OVERVIEW OF EVALUATION PROCESS FOR RMB LANE ENFORCEMENT



Source: Reference 1.

TYPE OF HOV LANE SEPARATION	LANE VIOLATION RATE	REFUGE AREA	ENGINEERING-RELATED ENFORCEMENT PROBLEMS
Non-Separated:			
Marin 101	21.5%	Minimal	Narrow lanes and minimal median make it desirable to escort violators across heavy traffic to shoulder.
Buffer-Lane:			
Alameda I-580	30.5%	Median Lane	Median occasionally used for enforcement. Majority of violators are escorted to right shoulder or apprehended after leaving lane.
San Bernardino Busway (East End)	8.8%	Buffer strip	Buffer strip is used as a refuge area for enforcement, or violator is escorted to far right shoulder.
Physical Barrier:			
San Bernardino Busway (West End)	3-4%	Bus Stations, Widened Refuge Areas	Violators are stopped at bus stations, or pulled over in marked refuge areas.

Detailed descriptions of each of these projects may be found in the Study Design. (Reference 3)

Ramp Bypass Lanes. In the case of ramp bypass lanes, the full spectrum of lane designs represented on California freeway ramps was tested to determine the impact of design characteristics on enforcement and violations. Existing bypass lanes were classified in groups according to a number of important geometric features, design choices, and performance characteristics, including the visibility of the enforcing officer and the current violation rate. In developing a sampling framework, three levels of officer visibility and ramp violation rates were defined:

OFFICER VISIBILITY:	RAMP VIOLATION RATES:
- Not visible;	- High (over 12%);
- Queue-dependent;	- Medium (12% to 6.5%);
- Visible.	- Low (under 6.5%).

The visibility of the enforcing officer was rated from the driver's point of view as he entered the ramp. If the enforcing officer could be seen as soon as the driver was on the ramp, enforcement was classified as visible; if the officer could not be seen until a violator passed the meter, enforcement was classified as not visible; if the visibility of the officer depended on the position of the driver in the queue on the ramp, enforcement was classified as queue-dependent.

In computing the ramp violation rate, the number of drivers using a bypass lane illegally has been expressed as a percentage of the total number of vehicles using the ramp (see Glossary). This is a somewhat more stable statistic than the lane violation rate, which depends both on the number of violators using the lane illegally and on the number of buses and carpools using the HOV lane legitimately. A more complete comparison of these two statistics may be found in the Study Design. (Reference 3)

Exhibit 1.7 illustrates several of the critical engineering measurements considered in classifying ramps for evaluation purposes. In addition to ramp violation rate and officer visibility, other classification criteria included the characteristics of the area served by the ramp (i.e., residential, industrial), ramp geometry (i.e., diamond, loop), availability of a refuge area for enforcement, the length of time a ramp had been operating, freeway performance in the vicinity of the ramp, and the existence of any special engineering problems (i.e., turning lanes which can "trap" single drivers in the carpool lanes). In addition to the variety of characteristics available for analysis on existing ramps, certain innovative engineering options were introduced and tested during the study. These include:

- Metered HOV bypass lanes;

- Special signing and striping; and

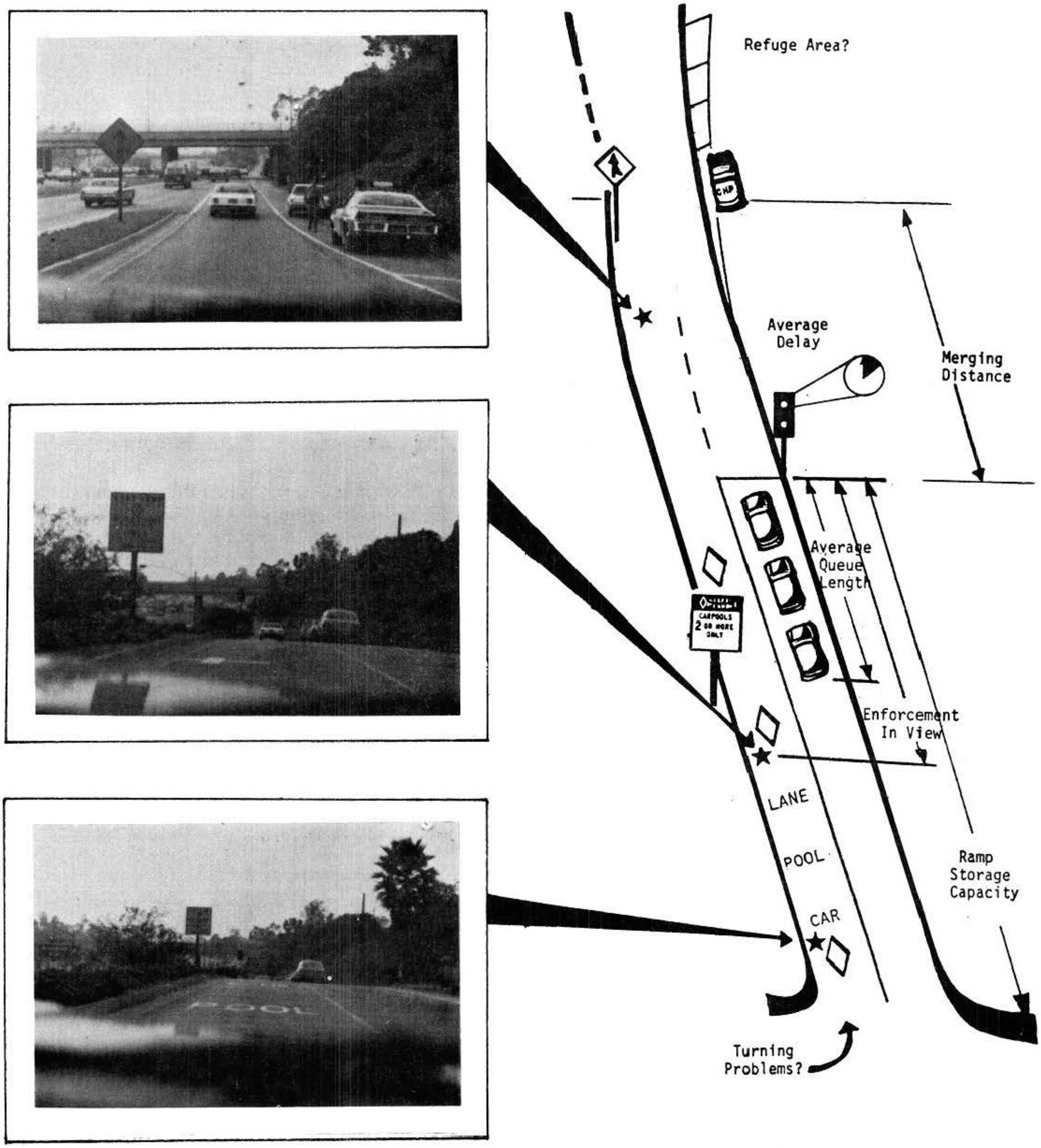
- Separated HOV bypass lanes.

Roughly one-third of the more than 130 ramp bypass lanes operating in Los Angeles at the start of the study were classified with respect to violation levels, officer visibility, and the other characteristics listed above.

Appendix C classifies over 40 Los Angeles bypass lanes in a three-by-three matrix reflecting different categories of violation rates and officer visibility. Seven bypass lanes in San Diego, including three freeway-to-freeway ramps, and two bypass lanes in the San Francisco Bay Area underwent a similar classification. In addition, sixteen new bypass ramps introduced in the course of the study in Los Angeles and San Diego were classified and violations and enforcement activities were monitored from the first day of operations on these projects. A small sampling of metered ramps without bypass lanes was also investigated, along with the preferential lanes on the San Francisco/Oakland Bay Bridge.

Exhibit 1.7

CRITICAL RAMP MEASUREMENTS



1.4.2 Enforcement Options Evaluated

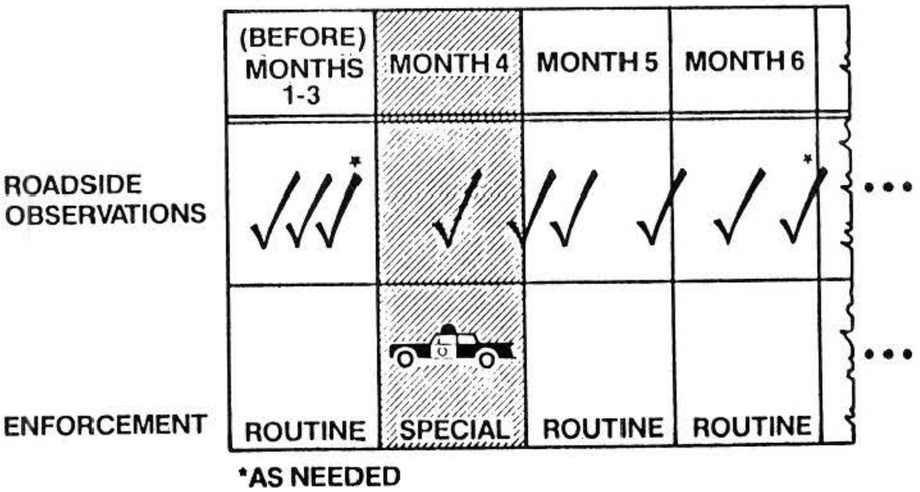
In considering enforcement, the key factors addressed were the staffing levels and deployment strategies required to achieve a specified violation level on a particular HOV project. Three general types of enforcement activities were studied:

1. Routine enforcement activities, or those enforcement activities randomly conducted in concert with the normal assortment of duties undertaken by a uniformed police officer;
2. Special enforcement activities, which entail the specific planning, scheduling and application of police activities on an HOV facility for a period of time, as when a patrol car is specifically assigned to a particular bypass ramp; and
3. Selective enforcement activities, which represent a combination of both routine and special enforcement.

During the study, different levels and combinations of routine and special enforcement were tested to ascertain their effectiveness in controlling violations both on newly opened projects and those that were operational for some time. CHP officers were assigned, singly or in teams, to particular bypass lanes and other TSM projects for a specified number of days over periods of one, four, or twelve weeks. Typically, special enforcement assignments covered the entire peak period for one, two, or four days per week. In addition, an enhanced version of routine enforcement was studied in which every beat officer on duty during the morning and evening peaks was instructed to spend ten minutes per day on ramp enforcement.

1.4.3 Data Collection Patterns

A typical pattern of field observations for a specific HOV project is shown below.



*AS NEEDED

The pattern called for two or three days' observation of violation rates prior to the introduction of special enforcement activities, followed by as many as five observations during the two months following these activities. The need for the last observation in each sequence of observations was determined by applying pre-specified testing procedures to earlier observations in the sequence (see Reference 3).

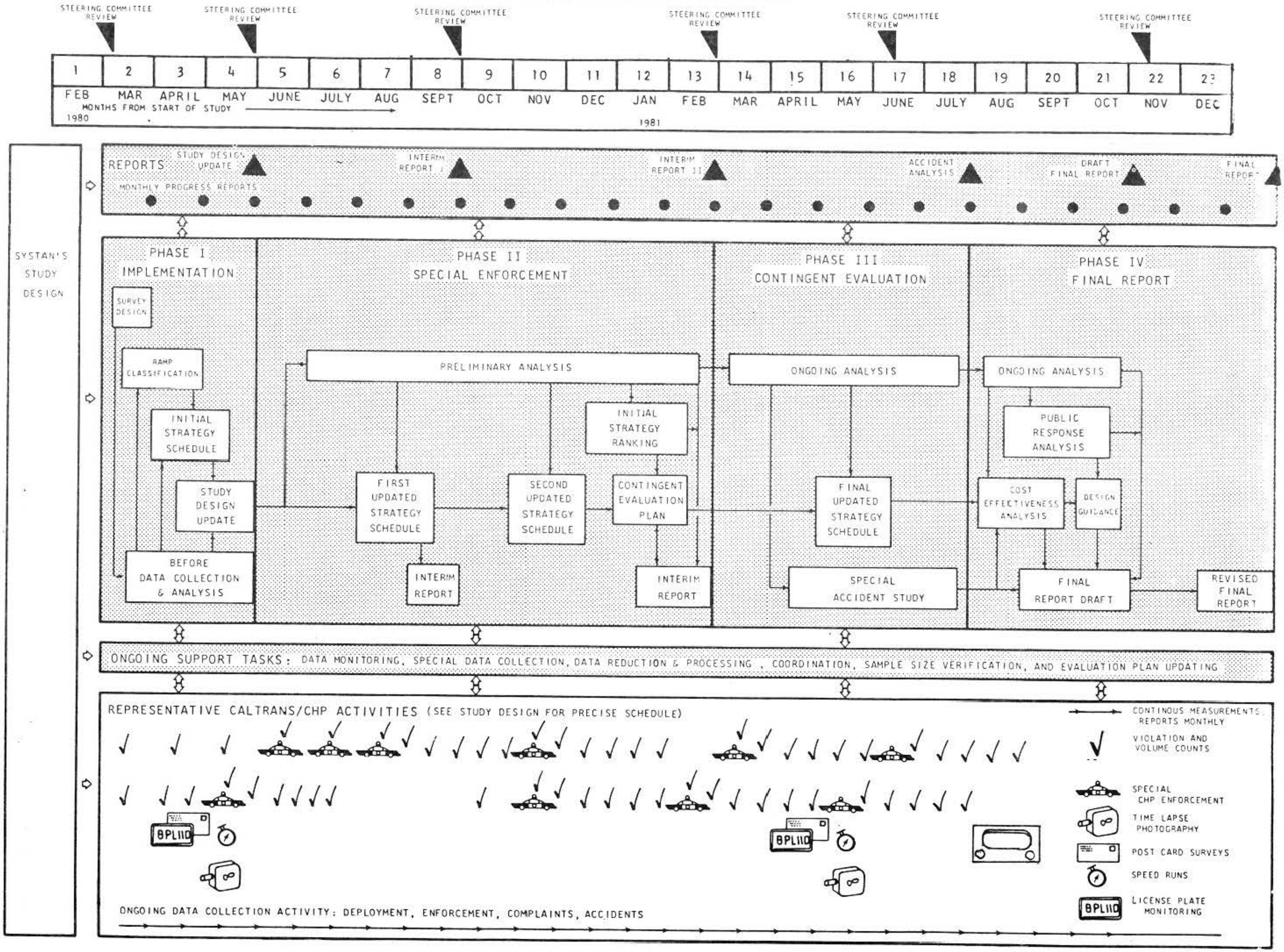
1.4.4 Schedule of Evaluation Activities

The evaluation schedule covered nearly two years, with interim reports prepared after the sixth and twelfth months. Exhibit 1.8 presents the schedule of evaluation activities followed over the length of the project. The first year began with a three-month implementation phase, followed by two waves of special enforcement activities covering the next nine months. Throughout the evaluation, experiments were scheduled sequentially, so that the results of ongoing analysis and the observations of enforcement personnel could be used to direct subsequent testing. Thus the results of the first two waves of enforcement were used to direct personnel assignments during two subsequent enforcement waves and to specify the combinations of enforcement, engineering, and education to be assessed during the final phase of the evaluation.

1.5 REPORT ORGANIZATION AND CONTENT

The final report covers the full span of the project, including the implementation phase, pre-enforcement surveys, four waves of special enforcement activities, and investigations of special design features, safety aspects, and the cost effectiveness of TSM project enforcement. Chapter 2 addresses enforcement impacts, reviews traditional enforcement approaches, investigates the immediate and longer-term effects of different enforcement tactics, and explores the relationship of citations and penalties to violation rates. Chapter 3 examines those questions of project design having a bearing on enforcement and violation rates, while Chapter 4 addresses the safety implications of ramp metering, ramp bypass lanes, and mainline HOV lanes. Chapter 5 discusses public information programs and driver attitudes, as revealed in surveys and investigations of individuals driving records. Chapter 6 analyzes the cost and effectiveness of different enforcement approaches, and recommends proposed approaches for enforcing California's current and future HOV facilities. Appendices contain a list of references (Appendix A), a glossary of terms (Appendix B), a listing of ramps by enforcement visibility and violation category (Appendix C), schedules of special enforcement activities (Appendix D), summaries of ramp violation rates for all four enforcement waves (Appendix E), delays encountered on metered lanes before and after the first enforcement wave (Appendix F), survey forms (Appendix G), and survey response rates (Appendix H).

EXHIBIT 1.8 EVALUATION SCHEDULE



2. ENFORCEMENT IMPACTS

This Chapter discusses the effectiveness of different enforcement levels and strategies in reducing occupancy violations on ramp meter bypass lanes, mainline HOV lanes, and exclusive toll plaza lanes. Traditional enforcement approaches are reviewed, the immediate and long-term effects of special enforcement activities are documented, and the relationship of deployment times, citation rates, and bail schedules to occupancy violations is analyzed. The Chapter also addresses the impact of enforcement activities on traffic flow and ramp delay.

2.1 RAMP METER BYPASS LANES

2.1.1 Historical Enforcement Levels

Prior to the start of this study, the CHP assigned relatively low priority to the enforcement of ramp bypass lanes. Most CHP Area Commanders established policies of routine enforcement, so that available personnel enforced the lane restrictions only after attending to regular patrol duties. To document the precise level of routine enforcement normally accorded to specific ramp bypass lanes, the CHP collected and compiled citation statistics for a sampling of over forty ramps at the outset of this study. Exhibit 2.1 summarizes the total number of 21655.5 citations issued prior to the special enforcement phase of the study on each of the Los Angeles and San Diego ramps designated in the Study Design. In effect, these statistics represent a ramp-by-ramp sampling of routine enforcement levels. As can be seen in Exhibit 2.1, the average routine citation rate at the outset of the study was generally low, and rarely exceeded one ticket per ramp per weekday. Those ramps with citation rates exceeding one ticket per day were ramps with relatively high violation rates (i.e., ramp violation rates exceeding 12%).

Prior to the initiation of special enforcement activities, routine enforcement practices led to an average citation rate of 0.27 tickets per ramp per weekday on all bypass lanes in Los Angeles and San Diego, or approximately one ticket per week per ramp. Because the current study represents the first time that citation statistics have been assembled on a ramp-by-ramp basis, it is impossible to trace the historical enforcement pattern for a specific ramp. It is possible, however, to trace historical citation rates for individual CHP Command Areas. Historical rates for participating CHP areas during 1979 are listed in Exhibit 2.2. A comparison of these 1979 rates with baseline levels recorded in the spring of 1980 suggests that the issue rate for 21655.5 citations was increasing slightly in most CHP areas prior to

Exhibit 2.1
HISTORICAL ENFORCEMENT LEVELS ON SAMPLE RAMP BYPASS LANES

CHP Area	**PRE-ENFORCEMENT DATA (APRIL–JUNE 1980)**		
AM/PM Ramp (Fwy)	**Ramp Violation Rate (%)**	**Number of Citations**	**Citation Rate (per week day)**
GLENDALE			
AM Burbank (LA5)	3.8	0	0
AM Tuxford (LA5)	6.8	0	0
PM Hollywood Way (LA5)	3.5	0	0
PM Colorado (LA5)	2.4	14	0.95
SANTA FE SPRINGS			
AM Lakewood N/B (LA91)	7.6	0	0
AM Whittier W/B (LA605)	4.0	3	0.12
AM Firestone (LA605)	16.9	18	0.72
PM Whittier E/B (LA605)	8.1	0	0
PM Imperial Hwy (LA605)	3.8	10	0.40
PM South St. (LA605)	10.8	1	0.04
PM Beverly (LA605)	3.8	0	0
PM Alondra (LA605)	6.4	4	0.16
CENTRAL LOS ANGELES			
AM Western E/B (LA10)	20.1	7	0.19
AM Florence (LA11)	31.1	48	1.33
AM Vernon (LA11)	19.5	36	1.00
AM Manchester E/B (LA11)	21.6	106	2.94
AM Venice (LA10)	13.8	87	2.42
PM Crenshaw (LA10)	31.7	16	0.44
PM Western W/B (LA10)	38.9	28	0.78
PM Los Feliz (LA5)	9.3	23	0.64
PM Pasadena (LA5)	10.4	10	0.28
WEST VALLEY			
AM Coldwater Canyon (LA101)	7.2	8	0.16
AM Laurel Canyon (LA101)	7.3	18	0.36
AM Woodman (LA101)	8.8	3	0.06
AM Burbank (LA170)	10.3	1	0.02
WEST LOS ANGELES			
AM National (LA10)	15.9	32	0.64
AM Bundy (LA10)	15.1	99	1.98
AM Wilshire (LA405)	19.6	0	0
AM Manning (LA10)	9.3	23	0.46
PM Olympic/Pico (LA405)	14.0	50	1.00
PM Moraga (LA405)	14.9	20	0.40
EL CAJON			
AM Spring Street	3.3	1	0.03
AM Rt. 94 – Rt. 94	0.6	1	0.03
AM College Grove	5.8	0	0
SAN DIEGO			
AM I-15 – Rt. 94	5.9.	13	0.26
AM I-805 – Rt. 94	5.6	9	0.18
AM 49th Street	1.2	0	0
AM Kelton	5.9	0	0
WESTMINSTER			
AM Katella (OR605)	3.9	0	0
PM Lakewood S/B (LA405)	13.1	47	1.18
PM Spring (LA405)	11.0	14	0.35
SANTA ANA			
AM Orangethorpe (OR91)	7.6	0	0
PM Orangethorpe (OR91)	9.2	0	0

Exhibit 2.2

HISTORICAL ENFORCEMENT LEVELS BY CHP AREA

	BASELINE DATA: SPRING 1980									
	Glendale	**Santa Fe Springs**	**Central L.A.**	**West Valley**	**South L.A.**	**West L.A.**	**Westminster**	**Santa Ana**	**El Cajon***	**San Diego***
Ramp Meter Bypass (RMB) Lanes	8	25	25	16	8	9	17	12	3	4
Average Officers on RMB Beats	4.30	10.20	33.20	13.90	8.7	13.0	6	4	5.7	5
Lanes/Officer	1.86	2.45	0.75	1.15	0.92	0.69	2.83	3.0	0.53	0.80
Daily Citations per Officer	0.23	0.35	0.37	0.14	0.65	0.42	0.40	0.18	0.02	0.09
Daily Citations per Ramp:										
Spring, 1980	0.36	0.15	0.50	0.12	0.71	0.66	0.14	0.06	0.02	0.11
Annual, 1979	0.19	0.13	0.85	0.08	0.79	0.47	0.11	0.19	0.18	0.69

*Command Areas in San Diego Metropolitan Area the start of the study. Significant declines in citation rates occurred in the two San Diego areas, where past enforcement activities presumably left current violation rates so low that few violators could be found during the early study months. Citation rates in the Central Los Angeles area were also higher during 1979 than during the pre-enforcement period, reflecting unusually heavy special enforcement activities during the early months of that year.

In terms of the number of officers assigned to beats having ramp bypass lanes, daily citation rates in the Los Angeles area ranged from 0.14 tickets per officer in the West Valley CHP Area to 0.65 in the South L.A. Area. Citation rates were lowest in those areas (West Valley, Santa Ana, and Glendale) where bypass lanes had most recently been introduced. Officers in the two San Diego Command Areas (El Cajon and San Diego) logged fewer daily citations than officers in any of the Los Angeles Command Areas, largely because the ramp violation rates in the border city were significantly lower than those in Los Angeles.

2.1.2 Enforcement Levels and Tactics

Special Enforcement Schedules. Four waves of special ramp enforcement activities were scheduled in Los Angeles and San Diego over the course of the project. The approximate timing of each wave is listed below:

First Wave:	June to September	1980
Second Wave:	September to December	1980
Third Wave:	January to April	1981
Fourth Wave:	May to August	1981

During each enforcement wave, officers were assigned to particular ramps for a specified number of days each week for periods of one week, four weeks, or twelve weeks. These special assignments were generally applied randomly and interspersed with periods of routine enforcement. Exhibit 2.3 contains a sample enforcement schedule for the fourth wave of enforcement carried out by the indicated command areas in the CHP's Southern Division (covering the major Los Angeles metropolitan area). Appendix D contains similar schedules for each wave of enforcement undertaken by the Southern Division and the Border Division (covering Orange County and the San Diego metropolitan area). The timing of special enforcement activities in both Divisions was staggered to smooth the data collection load imposed on CALTRANS personnel.

During the first wave of enforcement, special enforcement efforts were applied randomly to ramps in different violation and visibility categories. Assignments during subsequent waves reflected the results of previous waves, as well as a desire to test the widest spectrum of strategies on ramps with different violation history and geometric classifications. During the second wave, ramps with historically high violation rates tended to receive heavier doses of enforcement than ramps with lower violation rates. As the study progressed, short,

Exhibit 2.3 – SAMPLE ENFORCEMENT SCHEDULE
FOURTH WAVE OF SPECIAL RAMP ENFORCEMENT ACTIVITIES
CHP SOUTHERN DIVISION

	MAY				JUNE				JULY					AUGUST			
CHP AREA	4-8	11-15	18-22	25-29	1-5	8-12	15-19	22-26	29-3	6-10	13-17	20-24	27-31	3-7	10-14	17-21	24-28
GLENDALE																	
AM Burbank (LA5)											1 officer, 1 day/week, 4 weeks	▨	▨	▨			
AM Tuxford (LA5)											1 officer, 4 days/week, 4 weeks	▨	▨	▨			
x PM Hollywood Way (LA5)																	
x PM Colorado (LA5)																	
SANTA FE SPRINGS																	
AM Lakewood NB (LA91)			1 officer, 2 days/week, 12 weeks	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨			
AM Firestone (LA605)			1 officer, 4 days/week, 4 weeks	▨	▨	▨											
AM Whittier WB (LA605)			1 officer, 1 day/week, 4 weeks	▨	▨	▨											
x AM Del Amo (LA605)																	
x AM Artesia (LA91)																	
x PM Imperial Hwy (LA605)																	
PM Whittier EB (LA605)			1 officer, 4 days/week, 4 weeks	▨	▨	▨											
PM Bellflower (LA91)			1 officer, 2 days/week, 4 weeks	▨	▨	▨											
PM South St. (LA605)						2 officers, 2 days/week, 1 week											
x PM Beverly (LA605)																	
x PM Alondra (LA605)																	
x PM Studebaker (LA91)																	
x PM Slauson (LA605)																	
CENTRAL LOS ANGELES																	
AM Western EB (LA10)							1 officer, 4 days/week, 4 weeks	▨	▨	▨							
AM Florence (LA11)							2 officers, 2 days/week, 1 week										
AM Vernon (LA11)							2 officers, 2 days/week, 1 week										
AM Manchester EB (LA11)					1 officer, 2 days/week, 12 weeks	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
x AM Venice (LA10)																	
PM Crenshaw (LA10)										2 officers, 2 days/week, 1 week							
PM Western WB (LA10)										2 officers, 2 days/week, 1 week							
PM Los Feliz (LA5)							2 officers, 2 days/week, 4 weeks	▨	▨	▨							
x PM Pasadena (LA5)																	
WEST LOS ANGELES																	
AM National (LA10)									1 officer, 2 days/week, 4 weeks	▨	▨	▨					
AM Bundy (LA10)									2 officers, 1 day/week, 4 weeks	▨	▨	▨					
AM Wilshire (LA405)									2 officers, 1 day/week, 4 weeks	▨	▨	▨					
AM Manning (LA10)									1 officer, 2 days/week, 4 weeks	▨	▨	▨					
AM National (LA405)									2 officers, 2 days/week, 1 week								
x *AM Century EB (LA405)																	
x *AM Century WB (LA405)																	
x *AM Imperial WB (LA405)																	
PM Olympic/Pico (LA405)									2 officers, 2 days/week, 1 week								
PM Moraga (LA405)									1 officer, 2 days/week, 4 weeks	▨	▨	▨					
*PM Century (LA405)									1 officer, 1 day/week, 4 weeks	▨	▨	▨					
x PM Sunset (LA405)																	
x *PM Manchester (LA405)																	
SOUTH LOS ANGELES																	
*AM Imperial EB (LA405)					2 officers, 2 days/week, 1 week												
*AM El Segundo (LA405)					1 officer, 4 days/week, 4 weeks	▨	▨	▨									
x *PM Inglewood SB (LA405)																	
*PM Artesia (LA405)					2 officers, 2 days/week, 4 weeks	▨	▨	▨									
*PM Normandie (LA405)					1 officer, 1 day/week, 4 weeks	▨	▨	▨									
x *PM Hawthorne (LA405)																	
WEST VALLEY																	
AM Coldwater Canyon (LA101)											2 officers, 2 days/week, 1 week						
AM Woodman (LA101)											1 officer, 1 day/week, 4 weeks	▨	▨	▨			
AM Burbank (LA170)											2 officers, 2 days/week, 1 week						

KEY: ▨ *Special enforcement as indicated on specified ramp bypass lane.*
Routine enforcement at other times.

* *New bypass lanes.*

x *Ramps omitted from fourth enforcement wave.*

intensive enforcement assignments gradually supplanted the longer twelve-week assignments, which proved to be less cost-effective than either one-week or four-week stints. To the extent possible, each sample ramp was subjected to a different enforcement strategy during each wave of enforcement.

As indicated in Exhibit 2.3, special enforcement requirements were stipulated in terms of the number of officers to be assigned to a ramp, the number of days each week the officers were to be deployed at the ramp, and the direction of each special assignment. Within this framework each CHP Area assigned individual officers to meet the schedule requirements. Some areas elected to assign special enforcement activities to teams of one or two officers, while other areas rotated special enforcement duties among all the officers on a shift. Each area had the flexibility to reschedule special enforcement activities if officers assigned to ramp duty were called away to respond to freeway emergencies or undertake other high-priority duties.

Personnel assignments, citations, and violation rates were carefully monitored in the periods before, during, and after the application of special enforcement. (See Study Design, Reference 3) Particular attention was paid to the period after special enforcement had been replaced with routine enforcement, to determine the residual effect of special enforcement activities in deterring violators.

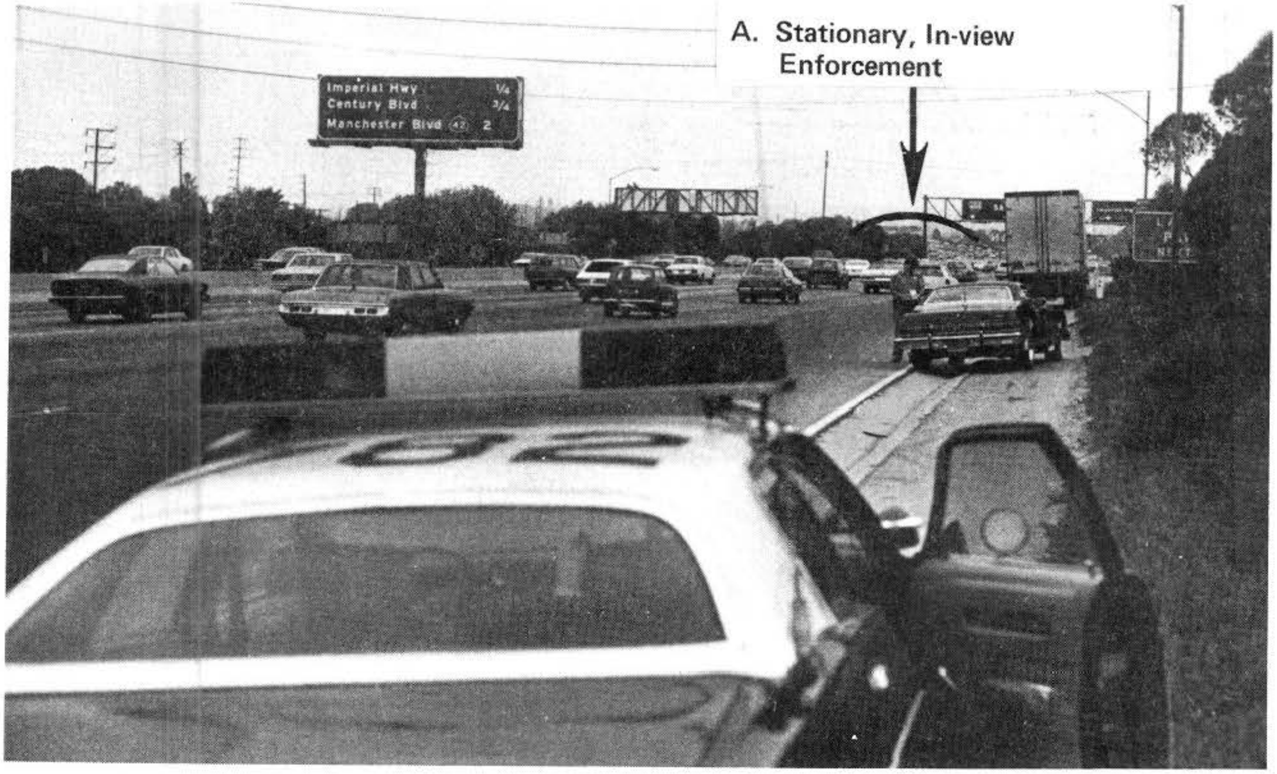
Special Enforcement Tactics. At the start of the study, the special enforcement tactics employed on the ramp bypass lanes varied from officer to officer and ramp to ramp. The most popular and effective tactic on ramps with ample refuge areas entailed parking the patrol car or motorcycle beyond the meter, and standing in place in the refuge area to wave violators over (see Exhibit 2.4). On ramps with scanty refuge areas, officers positioned themselves and their vehicles either ahead of the meter or behind it (see Exhibit 2.4), and pursued suspected violators along the freeway until they could be pulled over. Since this tactic left the officer at some distance from the ramp being enforced, it was less efficient both in producing citations and in providing an example to other ramp users than stationary enforcement.

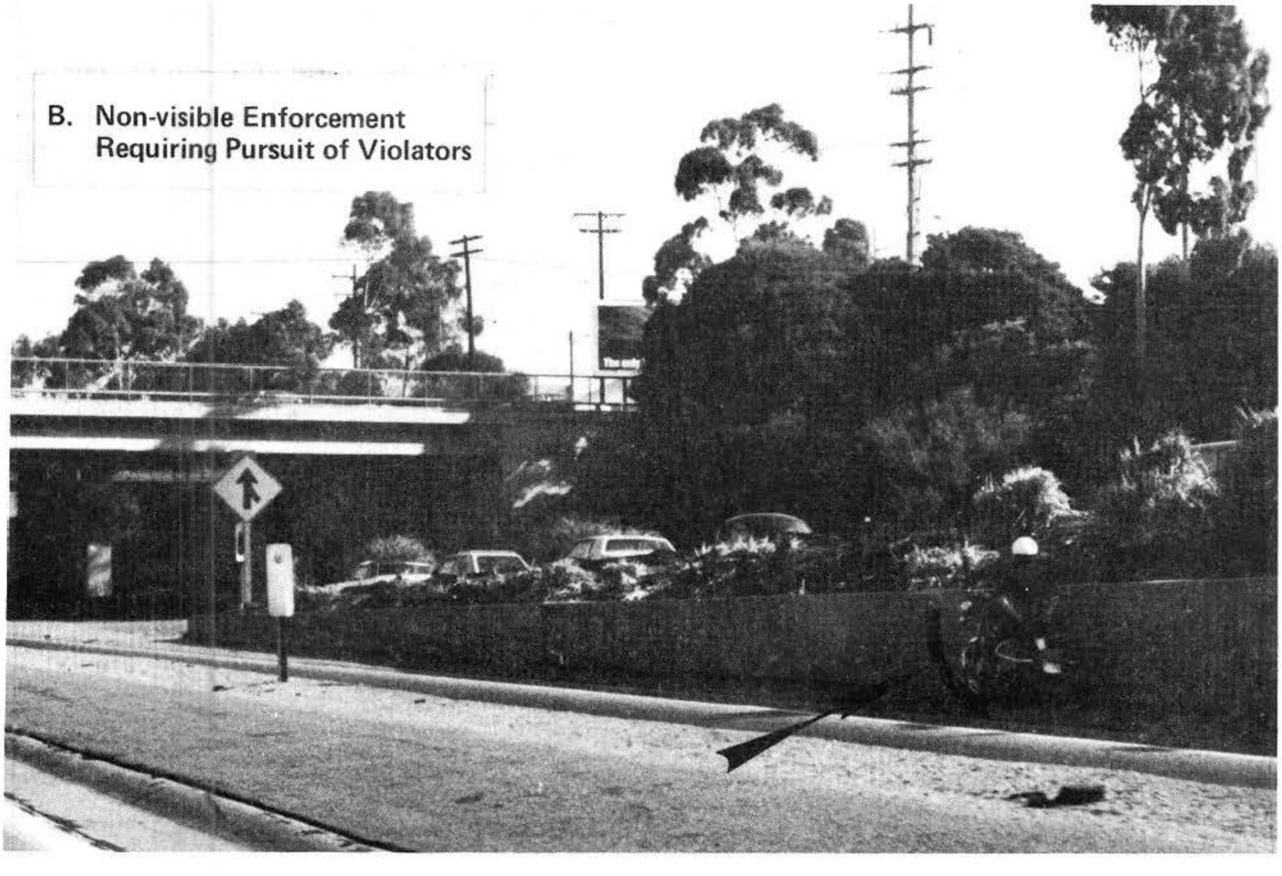
A portion of the variation in enforcement tactics observed during the first enforcement wave reflected experimentation on the part of officers faced with the problem of special ramp enforcement for the first time. In other cases, the variations reflected the predilections and preconceptions of particular officers. Certain officers preferred to position themselves behind the ramp meter and pursue violators (as in Exhibit 2.4) even when a refuge area was available for stationary enforcement. These officers wanted to be:

a) in a position to observe violations of the meter itself by cars in the metered lane, and

b) hidden from the sight of potential violators.

Exhibit 2.4
TYPICAL ENFORCEMENT TACTICS: RAMP BYPASS LANES


A. Stationary, In-view Enforcement


B. Non-visible Enforcement Requiring Pursuit of Violators

Since meter violations were a minor worry relative to occupancy violations, and since the deterring impact of a visible officer was a topic of interest in the study, officers were encouraged to follow stationary enforcement procedures whenever an adequate refuge area existed beyond the ramp meter. By the close of the study, most officers preferred and followed this mode of enforcement.

In an unanticipated variation in enforcement tactics, some officers preferred to stand in full view of potential violators even when the available refuge areas provided less visible enforcement positions. These enforcing officers explained reasonably that they wanted to be sure that the violators had plenty of time to see them and come to a safe stop in response to their signals. Typically the driver of an auto trying to merge onto a freeway will be looking to his left and edging to his right, away from the stream of freeway traffic and toward the standing officer. In such instances, in-place enforcement becomes more hazardous if attempted from less visible positions.

In view of the varying positions assumed by officers undertaking stationary enforcement of ramp bypass lanes, ramp classifications <u>vis-a-vis</u> visibility were altered to reflect actual practice following the first wave of enforcement. Where no consensus could be reached regarding a preferred enforcement position on ramps originally classified as non-visible, officers were instructed to assume special enforcement positions out of the view of potential violators for the duration of the study. This provided a consistent basis for investigating the impact of officer visibility on violations. The results of this investigation suggest that officers who enforced in full view of potential violators were just as effective in reducing violations as officers who assumed less visible positions (see Section 3.1.1).

<u>Routine Enforcement</u>. In addition to special enforcement activities, the CHP maintained routine levels of enforcement activities on all ramps throughout the evaluation. To investigate the impact of increasing routine enforcement levels, two CHP command areas were asked to modify their approach to routine enforcement after eight months of the study had passed. Beginning in late November, 1980, the two CHP Areas, Santa Fe Springs and West Los Angeles, were asked to modify their approach to routine enforcement by instructing each officer assigned to a beat with ramp bypass lanes to spend ten minutes a day enforcing these lanes. Officers were asked to vary their choice of ramps and enforcement times from day to day. This mandated level of routine enforcement was small enough to be met without interfering with activities more directly related to freeway safety, but large enough to represent a significant increase over traditional enforcement levels. This increase in routine enforcement supplemented special enforcement activities in the two areas, and a separate ten-ramp sample was monitored to determine the impact of the increase on violation rates.

2.1.3 Impacts of Special Enforcement

Overview. Exhibit 2.5 plots composite violation rates before, during, and after each wave of enforcement for the sample of ramps subjected to special enforcement activities. The first wave of enforcement was easily the most effective in reducing violation rates. During the first wave, special enforcement activities proved successful in reducing ramp violations on almost every ramp in the sample. Even the lowest levels of special enforcement (one officer, one day per week, for four weeks) had a significant, measurable impact in lowering violation rates. Moreover, violation rates tended to remain low for as long as four to eight weeks following the cessation of special enforcement activities.

Subsequent enforcement waves were less effective than the first in both the magnitude and duration of their effect on violation rates. Overall, violation rates dropped 32.7% following the first wave, but only 12.2%, 14.3%, and 16.9% during the second, third, and fourth waves. Although the relative effectiveness of special enforcement diminished somewhat following the first wave, heavier enforcement levels (enforcement two or more times a week) still caused violation rates to decline, and the lower enforcement levels generally managed at least to keep rates from rising and maintain earlier reductions. At the close of the fourth wave, the average violation rate on the ramps subjected to special enforcement stood at 6.5%, a 45.4% reduction below the 11.9% rate characterizing those ramps at the start of the study.[1]

Typical Violation Patterns. Exhibit 2.6 charts ramp violation rates on the Orangethorpe ramp leading to eastbound Route 91 in Orange County during the evening peak period. This graph reflects the general tendencies observed on most Los Angeles ramps. Historical counts collected prior to the current project are typically lower than the pre-enforcement counts collected in May and June of 1980, indicating a general trend of increasing violations. The average pre-enforcement ramp violation rate was 9.2%, reflecting an average of 82 violations per day. The violation rate dipped to 5.3% during the first wave of special enforcement, which covered a one-month period between mid-June and mid-July. During this period a motorcycle officer was stationed at the head of the Orangethorpe ramp two days each week for the entire period of meter operation. The officer issued 56 citations over this period, an average of 8 citations on each day of special enforcement, or 2.8 on each weekday during the four-week period. This citation rate was far higher than the average of .23 per ramp per day turned in on all ramps within the responsible CHP area during the early months of 1980. In fact, no tickets were recorded on the Orangethorpe ramp itself during the weeks immediately preceding special enforcement activity.

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[1] These percentages exclude those bypass lanes introduced during the course of the study.

Exhibit 2.5

COMPOSITE IMPACTS OF SUCCESSIVE SPECIAL ENFORCEMENT WAVES

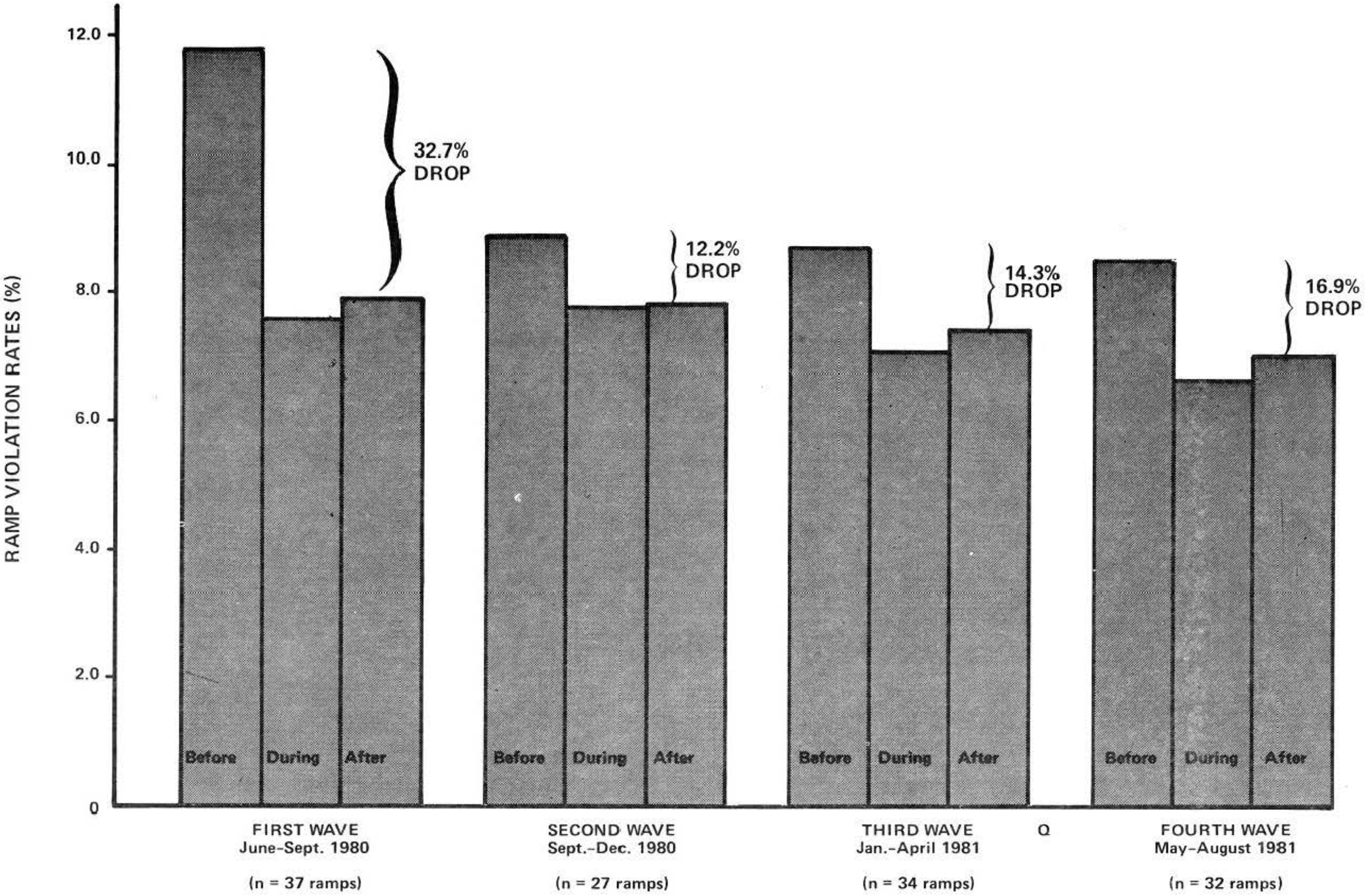
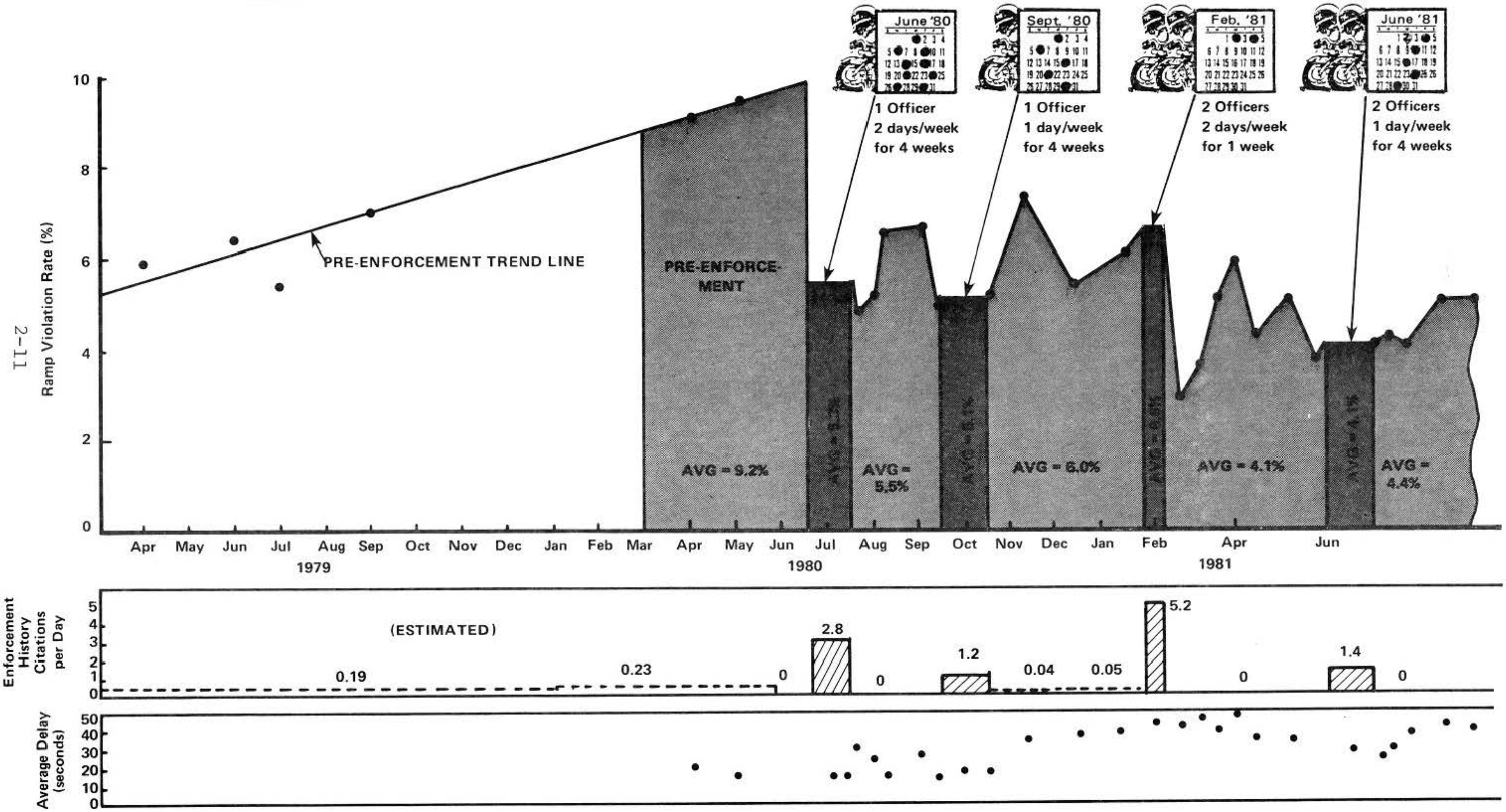


Exhibit 2.6

TYPICAL VIOLATION PATTERN
RAMP: ORANGETHORPE (PM) OR 91



Following the four-week enforcement period, the violation rate dipped still further, reaching a low of 4.7% (41 violations) during the first week following enforcement. The violation rate then began to climb, rising to 6.6% seven weeks after the special enforcement period. Rates never returned to pre-enforcement levels, however, and actually dipped again, dropping to 4.8% just prior to the second wave of enforcement.

During the second wave of enforcement, one officer was stationed at the ramp for one day during each week of a four-week period. The officer issued 24 citations during the four-week period, an average of 6 on each day of special enforcement. The first measurement taken after special enforcement ceased showed the ramp violation rate to be 5.1%. Statistical tests showed that the difference between this level and levels recorded immediately before the special enforcement period was not statistically significant (at the .05 level). Since the violation rates increased with subsequent measurements, it was concluded that the second enforcement wave had no impact on violation rates.

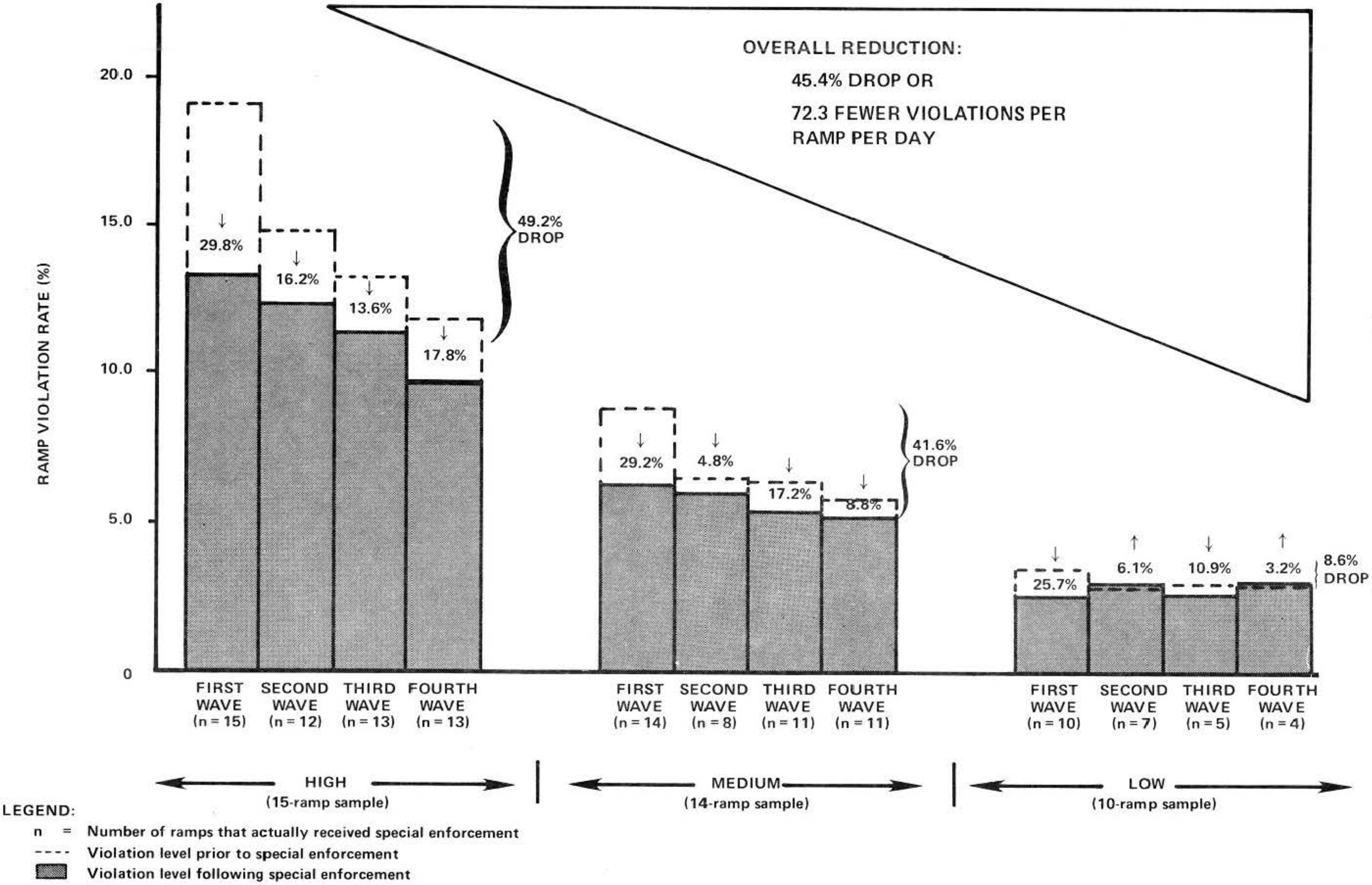
The third wave of enforcement on the Orangethorpe consisted of an intensive one-week period during which a pair of officers appeared at the ramp on two separate days. The officers issued 26 citations during the week, averaging 13 on each day of enforcement. Immediately after the third wave of enforcement, violation rates dropped to the lowest level recorded on the Orangethorpe ramp during the study, 2.8%. Violations increased thereafter reaching 5.1% four weeks after the special enforcement and 6.0% ten weeks later, before dropping again. Statistical tests showed that the difference between the four-week level of 5.1% and the pre-enforcement level was not statistically significant, so it was conservatively assumed that the residual impacts of the third wave ended after four weeks. Nonetheless, the average violation rate recorded following the third wave of enforcement, 4.1%, was significantly lower than the pre-enforcement level of 6.0%.

As in the case of the second enforcement wave, the fourth wave of special enforcement (two officers, one day per week for four weeks) had no measurable impact on violation levels, but did manage to maintain the lowered levels achieved following the previous enforcement wave. At the close of the fourth wave of enforcement, violation rates on the Orangethorpe ramp averaged 4.4%, a level 52% lower than the 9.2% rate recorded prior to the first enforcement wave.

<u>Results by Violation Category</u>. Exhibit 2.7 plots post-enforcement violation levels for the subset of sample ramps receiving special enforcement during each wave of enforcement. Results are aggregated for

Exhibit 2.7

REDUCTION IN RAMP VIOLATION RATES FOLLOWING FOUR WAVES OF SPECIAL ENFORCEMENT BY PRE-ENFORCEMENT VIOLATION LEVELS (A SAMPLE OF THIRTY-NINE RAMPS)



three categories of ramps, depending on violation rates measured prior to the first wave of enforcement. These measurements resulted in three ramp classifications by violation history.[2]

- High (ramp violation rates over 12%);
- Medium (ramp violation rates between 12% and 6.5%); and
- Low (ramp violation rates under 6.5%).

The overall impact of special enforcement was most pronounced on ramps where violation rates were originally classified as high. Enforcement was also effective on ramps with medium violation rates. Only the first wave of enforcement consistently caused violation rates to decline on ramps with low violation rates. Low-violation ramps often failed to respond to later enforcement efforts, and violation rates on these ramps actually increased following the second and fourth enforcement waves.

The lessened impact of each successive wave of enforcement, coupled with the difficulty of driving ramp violation rates below 5%, suggests that enforcement impacts are subject to a law of diminishing returns. For ramps with high and medium violation rates, successive applications of special enforcement tended to grow less effective in lowering violation rates. In the case of ramps with low violation rates, the later applications of special enforcement often failed even to maintain the lowered violation levels achieved following earlier waves. These results suggest that there is a practical limit on the reductions that can be brought about by enforcement, and consequently, that special enforcement efforts should not be expended in an attempt to make tolerably low violation rates lower still.

<u>Results by Enforcement Level</u>. Exhibit 2.8 charts the broad impacts of the three most common levels of special enforcement tested during the four enforcement waves. The three enforcement levels, each of which was maintained for four weeks are listed below:

1. One officer, one day per week, for four weeks;
2. One officer, two days per week, for four weeks; and
3. One officer, four days per week, for four weeks.

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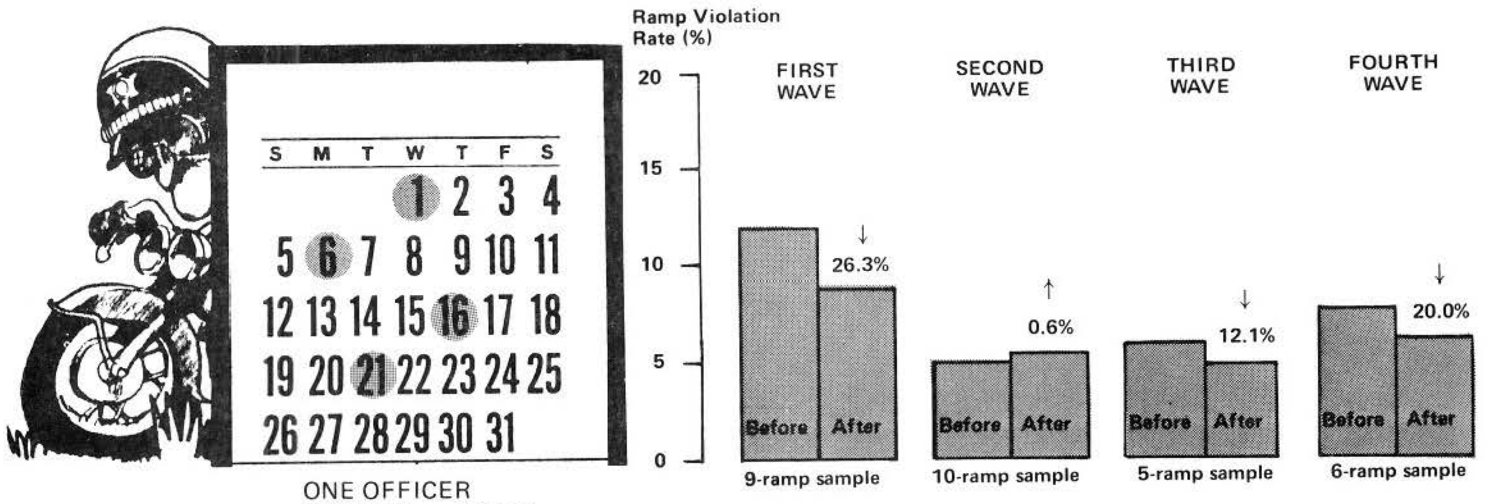
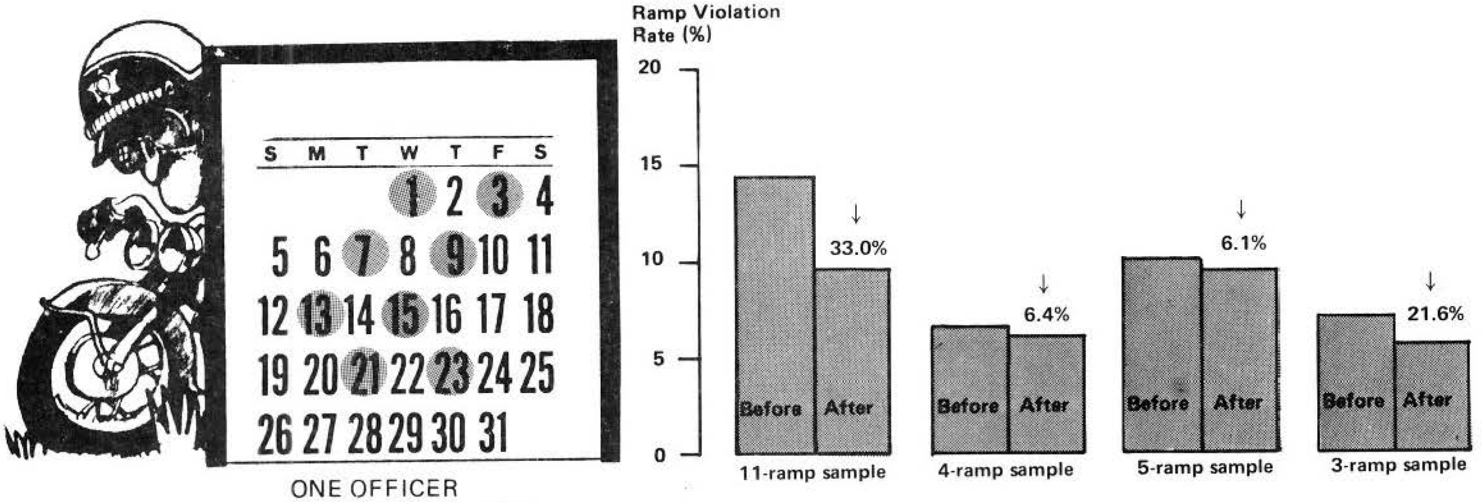
[2] In addition to classification by historical rate, ramps were also classified to reflect the visibility of the enforcing officer. This classification was not found to have a significant impact on the drop in violation rates following special enforcement, although officer visibility does appear to have a slight effect on the length of time violation levels remain low after special enforcement has ceased (see Section 3.1.1).

Exhibit 2.8

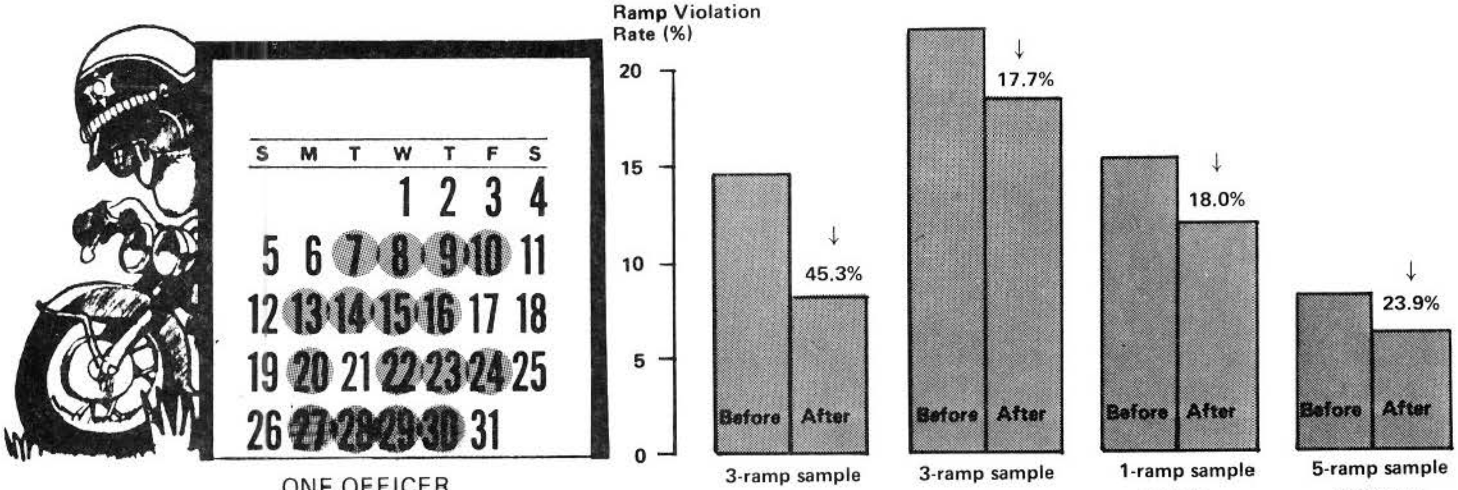
COMPOSITE IMPACTS OF DIFFERENT ENFORCEMENT LEVELS



ONE OFFICER
ONE DAY per WEEK
FOUR WEEKS



ONE OFFICER
TWO DAYS per WEEK
FOUR WEEKS



ONE OFFICER
FOUR DAYS per WEEK
FOUR WEEKS

The results of these three enforcement levels are plotted for composite ramps constructed by averaging the violation rates on appropriate ramps before and after the indicated levels of enforcement were applied. This method of aggregating results contains several inherent statistical flaws:

1. All post-enforcement measurements are averaged together, masking upward trends as the impact of enforcement wears off. For this reason, the "after" percentages in Exhibit 2.8 actually represent a conservative upper bound on the impact of enforcement.

2. The results are biased by the nature of the ramps selected to receive each level of enforcement. During the second wave and third wave, ramps with a history of low violation rates tended to receive lower levels of enforcement and did not respond as dramatically to these levels as did ramps with a history of higher enforcement levels. The heavy presence of these low-violation ramps in the composite statistics for low levels of enforcement activity biases these results.

3. Since few ramps received the same level of enforcement more than once, the composite results plotted in Exhibit 2.8 aggregate different sets of ramps during each wave of enforcement.

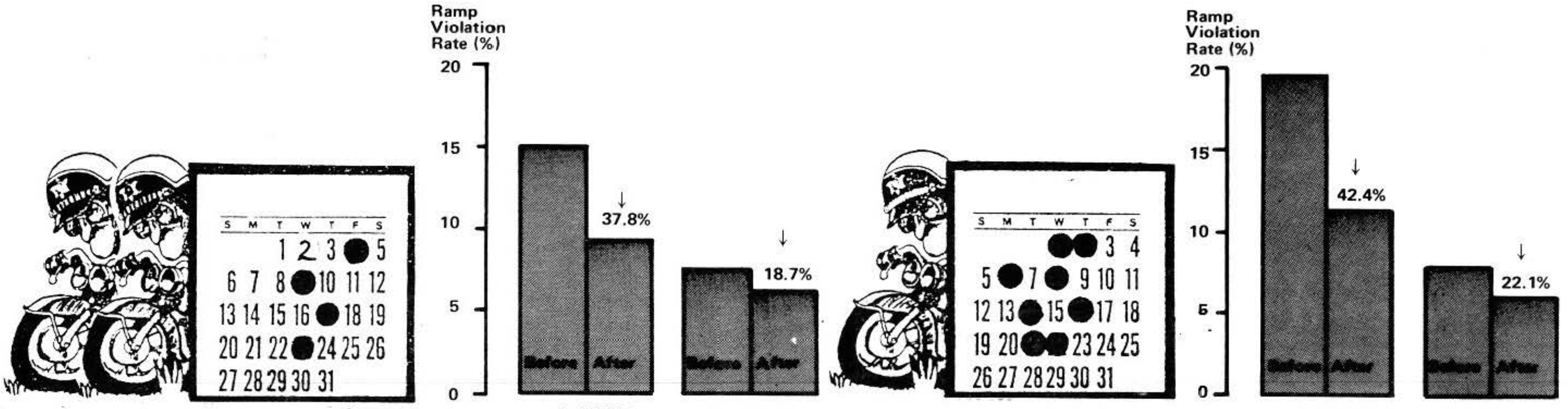
4. Finally, of course, the composites depicted in Exhibit 2.8 tend to obscure the results obtained on individual ramps. The reader interested in the ramp-by-ramp response of violators to special enforcement activities will find these responses catalogued in Appendix E for all four waves of enforcement.

In spite of these drawbacks, the composite results depicted in Exhibit 2.8 serve to summarize the impact of different enforcement levels with a minimum amount of distortion. Although subsequent waves of enforcement were less effective than the first wave in reducing violation rates, the heavier levels of enforcement applied during later enforcement efforts still brought about measurable drops in violations. For the subset of ramps receiving the heaviest level of enforcement (one officer, four days per week, for four weeks), ramp violation rates dropped 45% following the first wave while the same level of enforcement only caused 18% reductions during the second and third waves, and 23.9% during the fourth wave. As shown, ramp violation rates dropped 33% on the subset of ramps that had one officer enforcing two days a week for four weeks during the first wave. The same level of enforcement only caused 6% reductions during the second and third waves, and 21.6% reductions during the fourth wave. While even the lowest level of special enforcement applied during the first wave (one officer, one day per week, for four weeks) reduced ramp violation rates significantly, this same level when applied during the second wave was not sufficient even to maintain earlier reductions.

Effect of Pairing Officers. Pairs of officers were assigned to enforce different sets of ramps during each wave of enforcement.

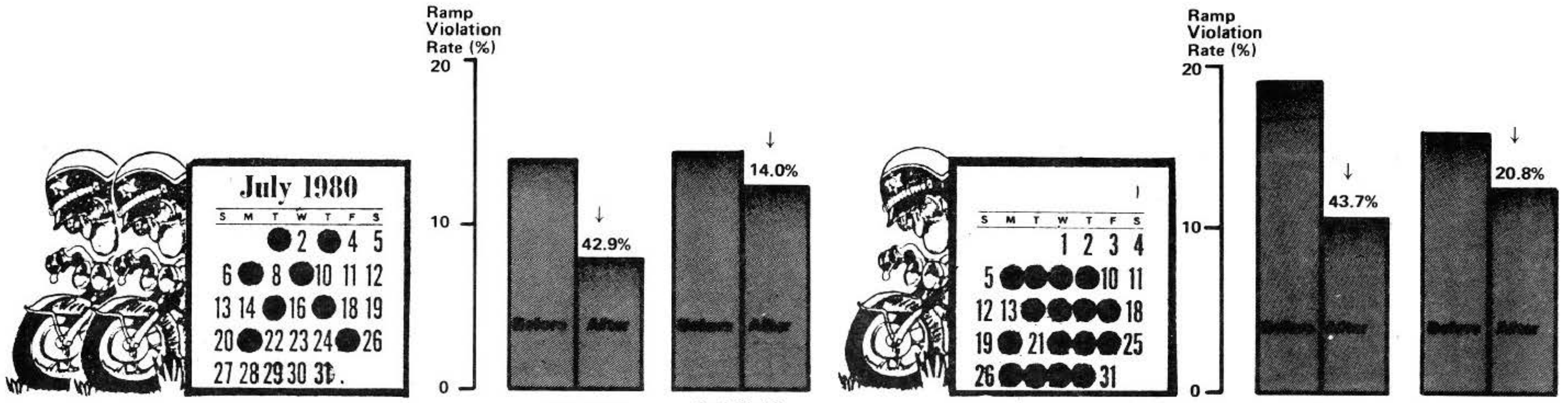
Exhibit 2.9

COMPOSITE IMPACTS OF PAIRING OFFICERS VS. SINGLE OFFICER



TWO OFFICERS
ONE DAY PER WEEK
FOUR WEEKS

ONE OFFICER
TWO DAYS PER WEEK
FOUR WEEKS



TWO OFFICERS
TWO DAYS PER WEEK
FOUR WEEKS

ONE OFFICER
FOUR DAYS PER WEEK
FOUR WEEKS

Exhibit 2.9 compares the violation rates recorded on these ramps before and after enforcement with the violation rates resulting when a single officer was assigned to comparable ramps for twice as many days. Ramps used in the comparison had similar ramp violation rates, enforcement histories, and levels of enforcement, as measured in officer hours of deployment. As shown in Exhibit 2.9, the results of the two approaches are roughly comparable, with the single officer consistently generating a slightly greater decline in violation rates than two officers working half the number of days.

Some officers preferred working in pairs on heavily violated ramps where an ample refuge area could accommodate several vehicles. With more than one officer enforcing a heavily violated ramp, fewer violators went unticketed, and help was always close at hand in the event that apprehended drivers became unruly while waiting to be ticketed.

Residual Impacts. Possibly the most important concern in investigating the impacts of different enforcement levels is the length of time after enforcement ceases that the effects persist -- the residual impact period. To estimate the duration of this residual period on different ramp bypass lanes, a survey of post-enforcement measurements was made, and each successive post-enforcement data point was compared with pre-enforcement data using a one-sided chi-square test at the .05 level of statistical significance.[3] The first post-enforcement measurement to be linked statistically with the pre-enforcement measurements (that is, the first post-enforcement measurements which could, with 95% certaintly, have come from the same distribution as the pre-enforcement measurements) is considered to represent a return to pre-enforcement conditions. This test is conservative for two reasons:

1. The one-sided statistical nature of the test means that some post-enforcement violation levels that are actually lower than any pre-enforcement level will be accepted as representing the pre-enforcement sample. However, any post-enforcement violation level that exceeds a pre-enforcement data point is automatically accepted as a return to pre-enforcement levels.

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[3] Since enforcement waves followed one another at two month intervals, some care was needed in defining appropriate pre-enforcement levels for each wave after the first wave. On ramps where violation rates had returned to their pre-enforcement levels at least once following the most recent wave of enforcement, the average of all field observations made after the violation rate first returned to its original level was used as a comparison base (i.e., the new pre-enforcement level) in determining the residual impact of the next wave. If a ramp failed to return to its pre-enforcement level following an enforcement wave, the last two field observations made prior to the start of the next wave of enforcement were taken as a reference base in determining subsequent residual impacts.

2. It is possible that in a sequence of measurements an apparent return to pre-enforcement conditions will be followed by a series of violation counts significantly lower than any pre- or post-enforcement counts. Although these lowered violation rates can reasonably be attributed to the special enforcement activity, the first-point return rule states that the residual impacts are over.

Even with these conservative rules for identifying a return to pre-enforcement conditions, the residual impacts of the first wave of special ramp enforcement activities were substantial. However, the residual impacts of each successive enforcement wave grew progressively weaker. Exhibit 2.10 plots the percent of test ramps returning to pre-enforcement levels over a period of eight weeks following each enforcement wave. Violation rates following the third and fourth enforcement waves generally returned to pre-enforcement levels somewhat quicker than rates following the second enforcement wave. The second wave impacts, in turn, had considerably less staying power than the violation reductions experienced following the first enforcement wave. By the twelfth week after special enforcement activities had ceased, one-third of the ramps receiving special enforcement during the first wave were still below pre-enforcement levels. At the same point following the second wave, only 7% of those ramps receiving enforcement were still below their post-first-wave violation levels. None of the ramps enforced during the third and fourth waves had failed to return to pre-enforcement levels at least once by the twelfth week following enforcement.

Exhibit 2.11 charts the effects of pre-enforcement violation levels on the residual impacts of the four waves of special enforcement. The greatest residual impacts were experienced on ramps with high violation rates, with low-violation ramps returning to pre-enforcement levels quickest. This relative ranking was maintained consistently following each enforcement wave (see Reference 5). Aggregating the results of all four waves, the median length of time preceding a return to pre-enforcement levels was four weeks for high-violation ramps, two weeks for medium violation ramps, and one week for low violation ramps.

Start-Up Strategies. The effectiveness of special enforcement in reducing violation rates on HOV projects which have been operational for some time suggests that the application of appropriate enforcement strategies early in the life of a project will affect future violation levels on that project. Whereas the earliest ramp bypass lanes opened in Los Angeles (Lakewood Boulevard and Hawthorne Avenue on LA 405, opened in 1973 and 1974, respectively) profited from the benefits of close CHP scrutiny from their earliest implementation, later installations received little special attention. To test the impact of different beginning enforcement strategies on violation rates over the length of a project, the first HOV bypass lanes to be opened during the current study were incorporated in the Study Design, photographed, classified, and scheduled for special enforcement treatment.

Exhibit 2.10

RESIDUAL IMPACTS OF SUCCESSIVE SPECIAL ENFORCEMENT WAVES

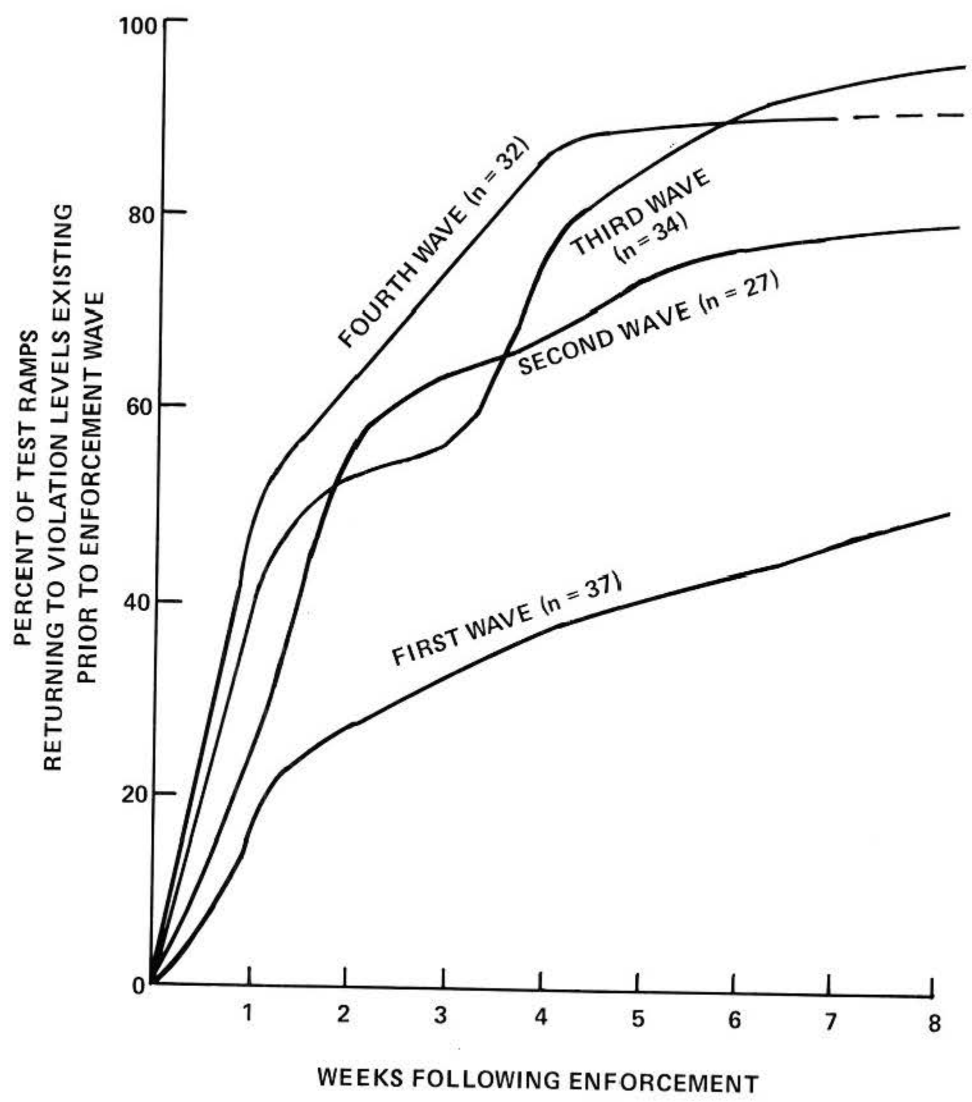
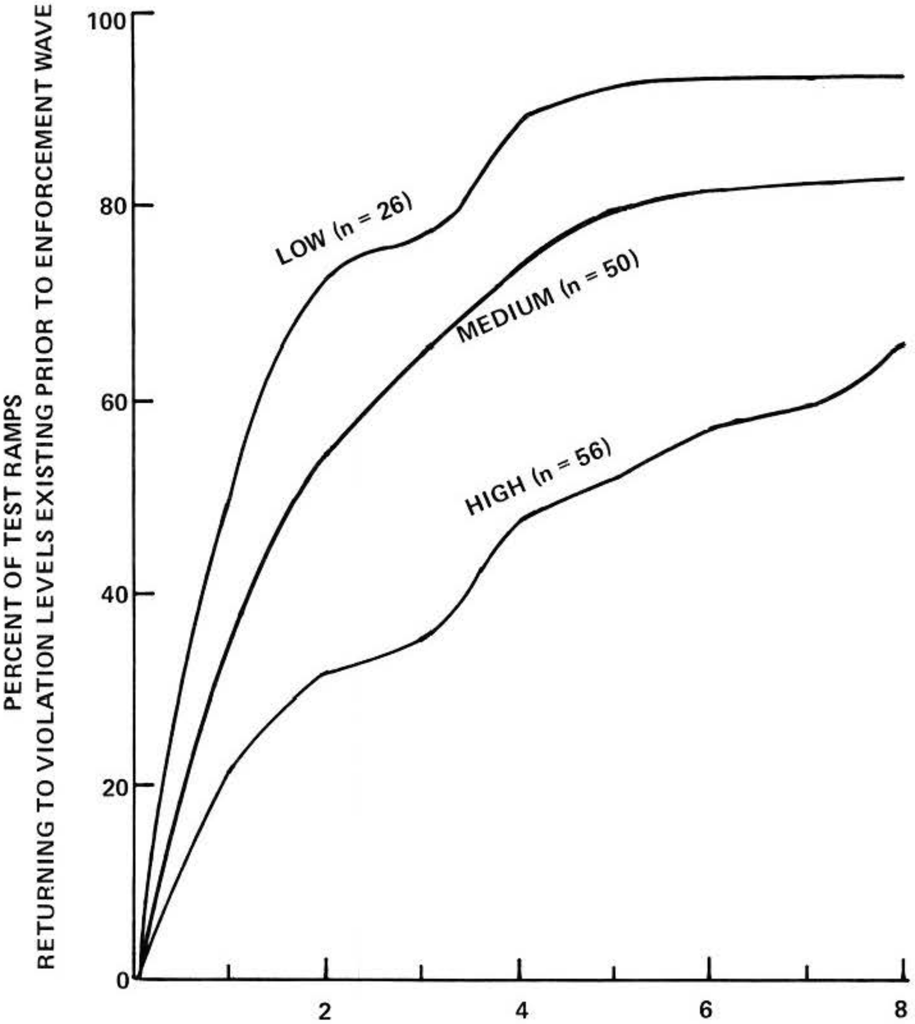


Exhibit 2.11

RESIDUAL IMPACTS OF ALL FOUR WAVES OF SPECIAL ENFORCEMENT BY PRE-ENFORCEMENT VIOLATION LEVELS



These lanes were opened in early July, 1980 on twelve ramps of the San Diego Freeway (LA 405) within the jurisdiction of the West Los Angeles and South Los Angeles CHP Areas. The new San Diego Freeway bypass lanes were particularly well suited as subjects for a special enforcement study, since the twelve ramps included several "matched pairs" of ramps having similar geometric configurations, visibility classifications, and neighborhood characteristics. Following a one-week grace period, during which verbal warnings were issued to violators, special enforcement activities were initiated on one ramp of each matched pair, with the other ramp receiving only incidental enforcement. The start-up schedule for special enforcement activities is listed below:

ENFORCEMENT RAMPS				CONTROL RAMPS (Routine Enforcement Only)		
TIME	RAMP	OFFICER VISIBLE?	INITIAL ENFORCEMENT LEVEL	TIME	RAMP	OFFICER VISIBLE?
AM	Imperial WB	No	(2 days/wk, 4 wks)	AM	Century WB	No
AM	Imperial EB	QD	(1/2 day/wk, 4 wks)	AM	Century EB	No
AM	El Segundo WB	No	(2 days/wk, 12 wks)			
				AM	Manchester EB	QD
PM	Century	No	(1 day/wk, 12 wks)	PM	Manchester	No
PM	Inglewood SB	QD	(2 days/wk, 4 wks)	PM	Hawthorne	QD
PM	Artesia	No	(1 day/wk, 4 wks)			
PM	Normandie	Yes	(1 day/wk, 4 wks)			

A two-month period of routine enforcement followed the initial enforcement wave on each of the seven ramps subjected to special enforcement. Following this, six of these seven ramps were incorporated in subsequent special enforcement waves and received varying levels of special enforcement at three month intervals. The seventh ramp, Imperial WB, received nothing but routine enforcement for the remainder of the study.

Exhibit 2.12 tabulates the average violation rates recorded on the set of sample ramps for the one-year period following their opening, while Exhibits 2.13 and 2.14 graph the individual violation rates recorded on the matched pairs of control and experimental ramps over time. The graphs provide a convincing testament to the value of early enforcement on HOV projects. In the case of each of the four ramp pairings, the ramp receiving special enforcement had significantly lower violation rates than its opposite number, which was accorded routine enforcement. In each case the difference was statistically significant (at the .05 level) and was maintained over the first year of project life. In two of the pairings, the highest ramp violation rate recorded on the ramp recieving special enforcement was lower than the lowest data point recorded on the ramp receiving routine enforcement. Given the natural volatility of ramp violation rates, this evidence of the effectiveness of early enforcements is particularly convincing. One of the pairings exhibiting the greatest difference between special and routine enforcement included the Imperial WB ramp, which received special enforcement only during the first month of its existence. The

Exhibit 2.12

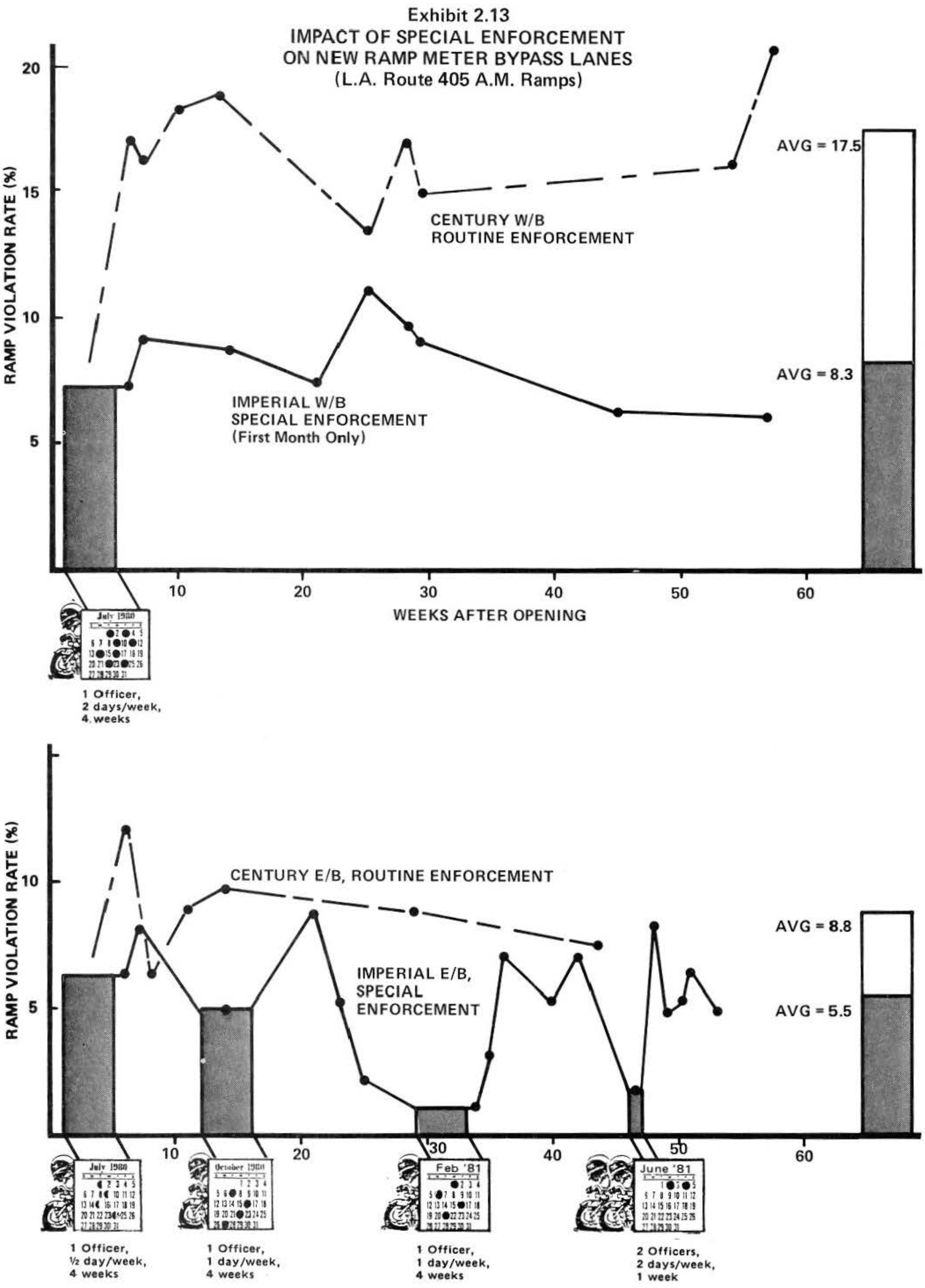
AVERAGE VIOLATION RATES AFTER ONE YEAR OF OPERATION ON RAMPS WITH AND WITHOUT SPECIAL START-UP ENFORCEMENT

(Los Angeles Route 405)

Ramps Receiving Special Enforcement					Ramps Receiving Routine Enforcement Only		
Time	**Ramp**	**Amount of Special Enforcement During First Year (Officer days)**	**Violation Rate After One Year**		**Time**	**Ramp**	**Violation Rate After One Year**
AM	Imperial WB	8	8.3%	↔	AM	Century WB	17.5%
AM	Imperial EB	14	5.5%	↔	AM	Century EB	8.8%
AM	El Segundo WB	32	5.4%				
PM	Century	20	9.6%	↔	PM	Manchester	18.0%
PM	Inglewood SB	20	3.0%	↔	PM	Hawthorne	7.0%
PM	Artesia	24	9.5%				
PM	Normandie	16	6.0%				
	Average	19	7.2%				14.0%

↔ Indicates ramps matched for comparison purposes

Exhibit 2.13
IMPACT OF SPECIAL ENFORCEMENT ON NEW RAMP METER BYPASS LANES
(L.A. Route 405 A.M. Ramps)



1 Officer,
2 days/week,
4 weeks

1 Officer,
½ day/week,
4 weeks

1 Officer,
1 day/week,
4 weeks

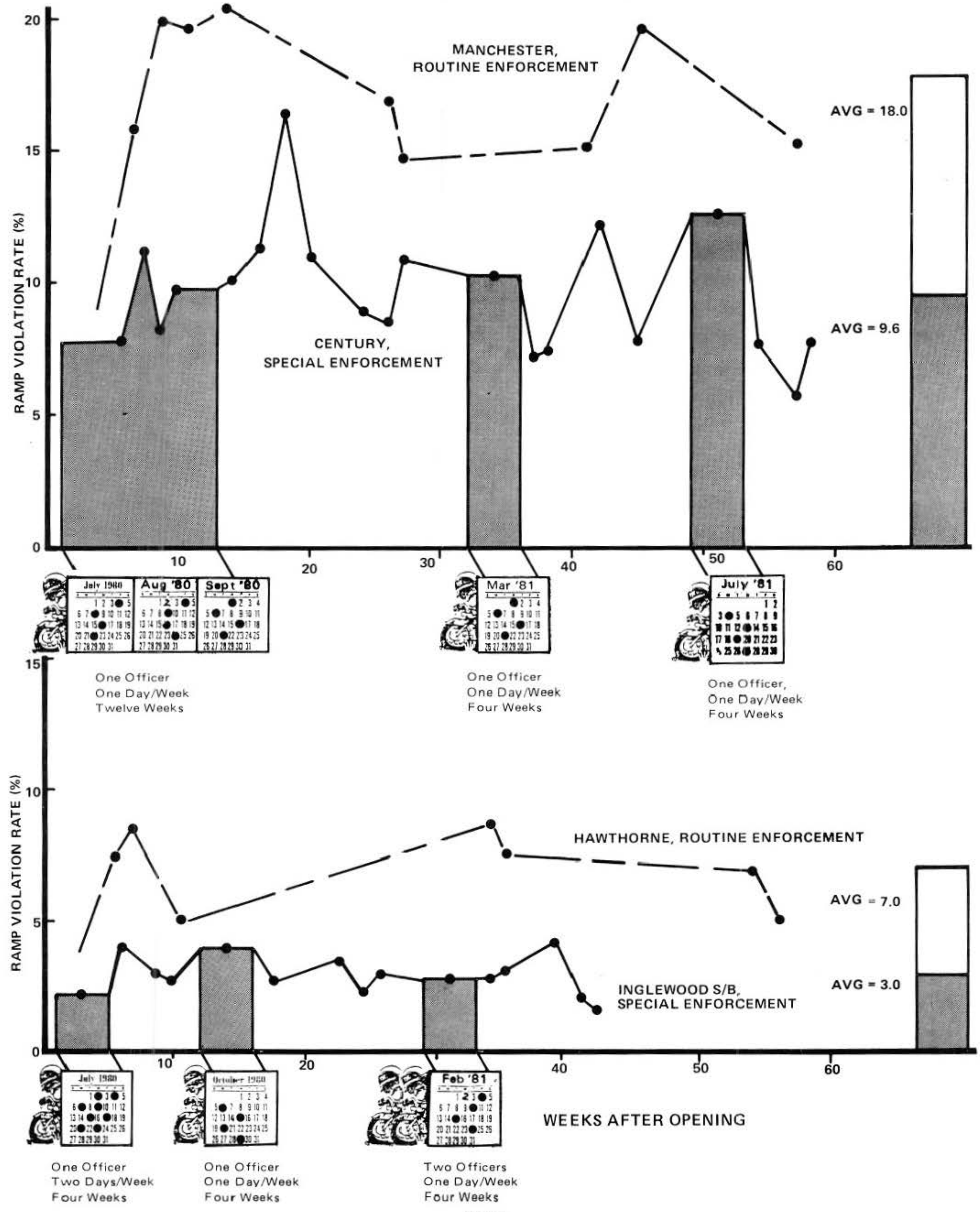
1 Officer,
1 day/week,
4 weeks

2 Officers,
2 days/week,
1 week

Exhibit 2.14

IMPACT OF SPECIAL ENFORCEMENT ON NEW RAMP BYPASS LANES

(L.A. Route 405 P.M. Ramps)



average violation rate recorded over this ramp's first year of operation was 8.3%, some 52% lower than the 17.5% level recorded on its control pairing, the Century WB ramp just 1.03 miles away. The composite violation rate recorded on the four paired ramps receiving special enforcement was 7.3%, as compared with 14.0% on the matched control ramps exposed only to routine enforcement.

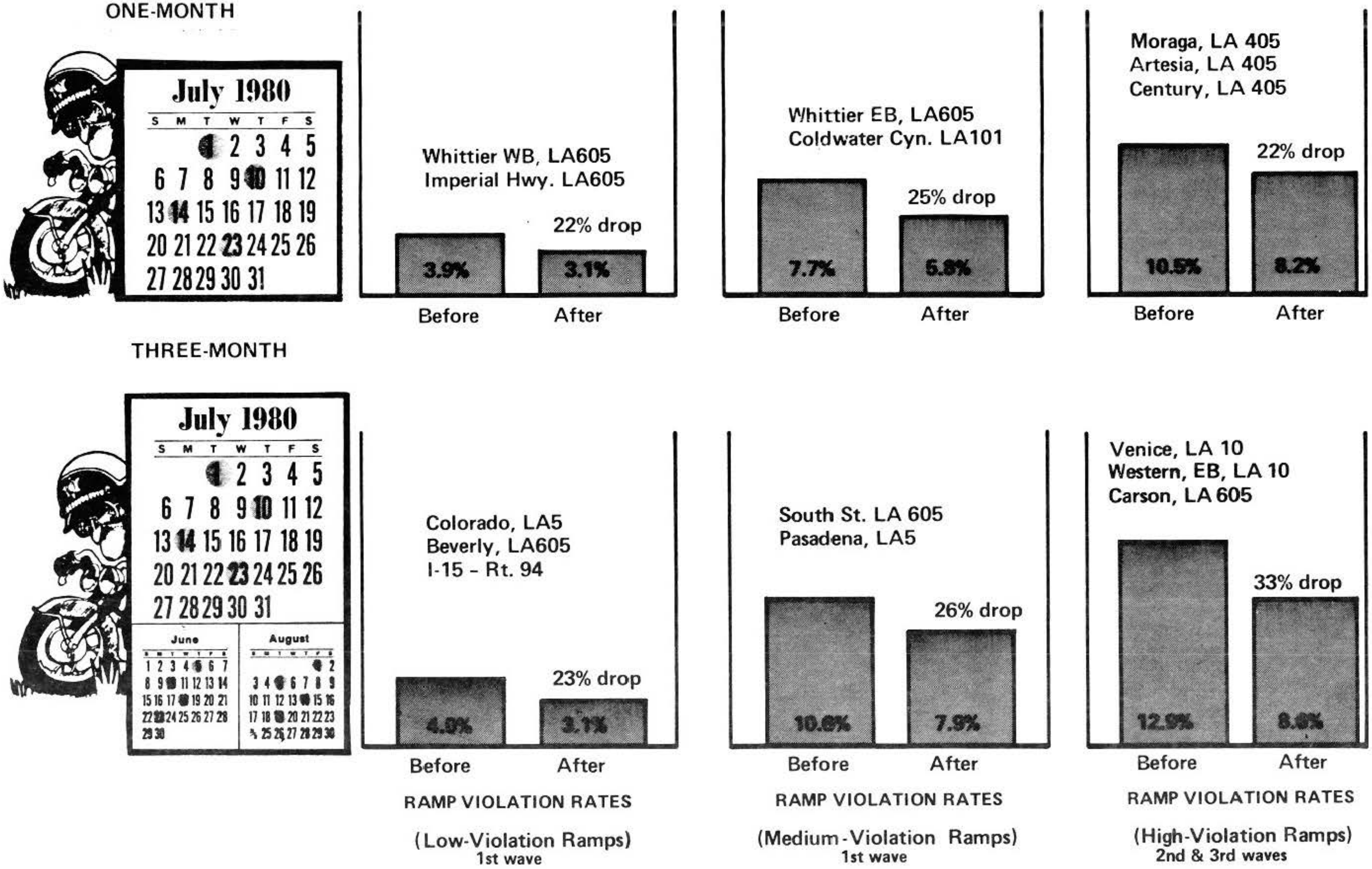
Violation rates on the routinely enforced ramps rose relatively rapidly, exceeding 15% within six weeks of the opening date on two of these ramps. This rapid rise suggests that Los Angeles drivers using the new lanes had enough past experience with bypass lanes in other areas to have formed opinions regarding the relatively low historical levels of CHP enforcement and the correspondingly low probability of violator apprehension.

Effect of Longer Enforcement Period. Exhibit 2.15 compares the impacts of one-month and three-month periods of special enforcement on sample ramps with low, medium, and high violation rates. Each ramp in the sample was visited by an officer once a week throughout the peak commute hours for a period of one or three months. At this low level of enforcement, the tabulated results show little difference between the impact of one-month and three-month enforcement periods in reducing ramp violation rates. Among the ramps with low violation levels, one month of enforcement during the first wave produced a 22% drop in violation rate while three months of enforcement during the same wave reduced the violation rate by 23%. The corresponding figures for ramps with medium violation levels initially are 25% and 26% respectively. It was only on ramps with high violation rates that the longer enforcement period appeared to have a greater impact on violation rates than the shorter one-month period. During the second and third enforcement waves, three months of enforcement caused violation rates on three high-violation ramps to drop 33%, while similar efforts over a one-month period caused a 22% drop on comparable ramps. Even though the three month period had a greater impact in this instance, the improved performance was not proportional to the additional effort expended.

The impacts of three-month enforcement periods on ramp violation rates were not significantly greater than those of one-month enforcement periods for other levels of enforcement (see below).

Exhibit 2.15

COMPOSITE IMPACTS OF ONE-MONTH AND THREE-MONTH ENFORCEMENT PERIODS
(ONE OFFICER, ONE DAY PER WEEK)



	3-MONTH PERIOD				ONE-MONTH PERIOD (Matching Ramps)			
ENFORCEMENT LEVEL	No. of Ramps	RVR Before	RVR After	% Change	No. of Ramps	RVR Before	RVR After	% Change
1 CHP, 1/2 day/week	3	8.0	7.1	-11.3%	3	5.9	4.9	-16.9%
1 CHP, 1 day/week								
-low violation ramps	3	4.0	3.1	-23 %	2	3.9	3.1	-22 %
-medium viol. ramps	2	10.6	7.9	-26 %	2	7.7	5.8	-25 %
-high viol. ramps	3	12.9	8.6	-33 %	3	10.5	8.2	-22 %
1 CHP, 2 day/week	2	8.2	4.5	-45 %	2	9.2	5.9	-36 %
2 CHPs, 2 days/week	1	11.3	5.8	-40 %	1	14.0	8.3	-41 %

For the lowest level of special enforcement tested (one officer, one day every other week), the shorter one-month period actually produced a greater percentage decline in ramp violation rates than the longer three-month period. In the case of the heaviest level tested (two officers, two days per week) comparable reductions resulted from both the longer and shorter periods. Twice-weekly visits by two officers to the Los Feliz ramp on the Golden State freeway in Los Angeles over a period of three months caused violation levels to drop 40%, while comparable levels of enforcement applied over a one-month period on the Olympic/Pico ramp leading to the San Diego freeway caused violation rates to drop 41%.

Just as there was no evidence that three-month enforcement periods were more effective than one-month enforcement periods in reducing violations, there was also no indication that the longer periods had a greater residual impact once special enforcement ceased. Exhibit 2.16 plots the percentage of test ramps returning to pre-enforcement levels over a period of eight weeks following the first wave of enforcement for two sets of sample ramps:

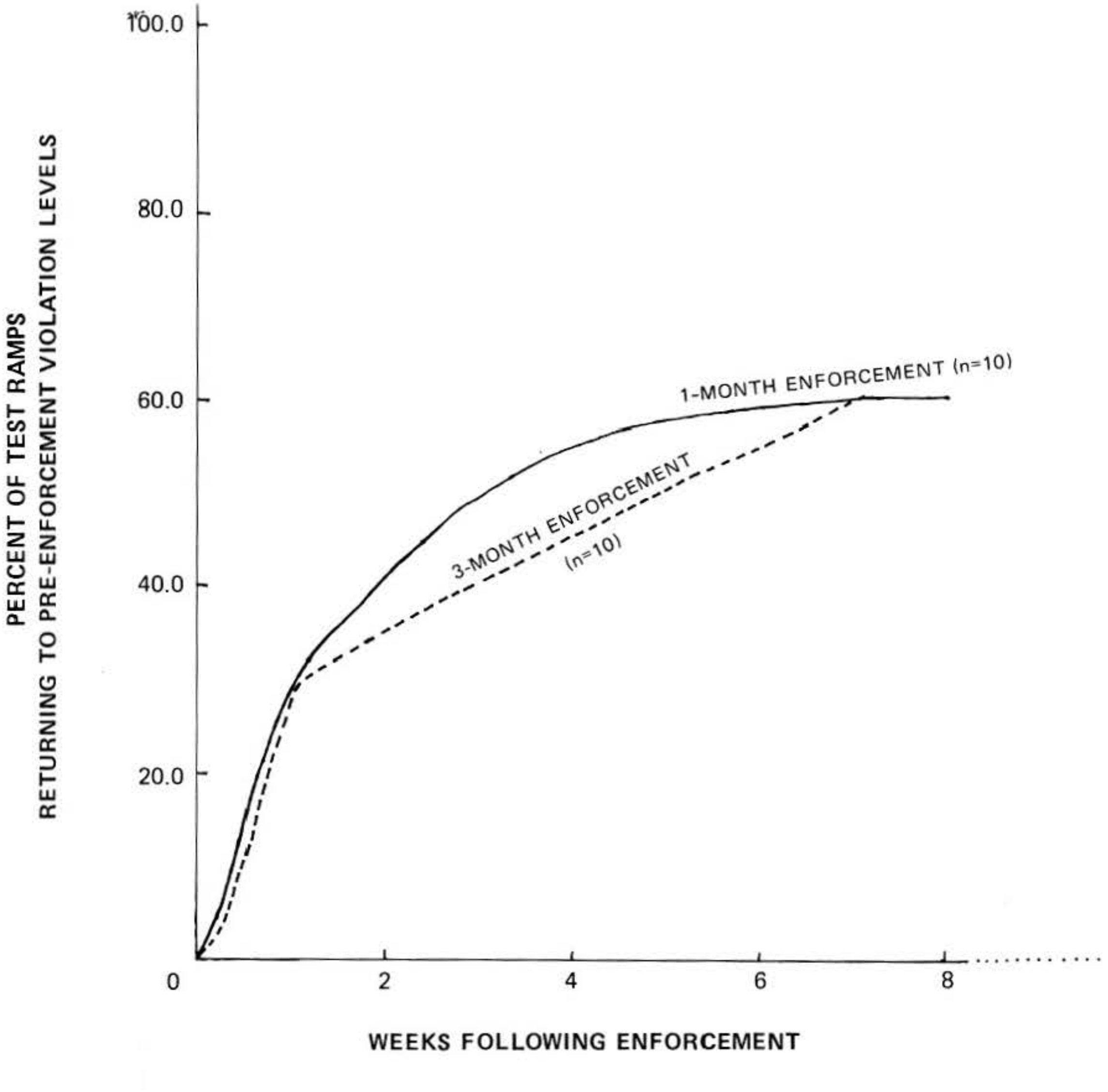
1. Ten ramps receiving three months of special enforcment.

2. A control group of ten similar ramps subjected to one month of special enforcement.

The ramps in Group 2 were selected to match the Group 1 ramps in terms of both historic violation rates and special enforcement levels. Thus each ramp in Group 2 closely resembled one of the Group 1 ramps in every important respect except the duration of special enforcement. As shown in Exhibit 2.16, there was little difference between the rate at which violations on the two groups of ramps returned to pre-enforcement levels. Thirty percent of the ramps in both groups returned to pre-enforcement levels within one week after special enforcement stopped, and sixty percent of both groups had returned to normal within eight weeks. Although the median time before pre-enforcement levels are reached was slightly longer in the case of three-month ramps, the difference was not statistically significant.

EXHIBIT 2.16

RESIDUAL IMPACTS OF ONE-MONTH VS. THREE-MONTH ENFORCEMENT FIRST WAVE OF SPECIAL ENFORCEMENT



Impacts of "Staccato" Enforcement. When analysis of the first two enforcement waves showed that three-month enforcement periods were not nearly as cost-effective as one-month periods, shorter "staccato" bursts of intensive enforcement (two officers, two days a week, for one week) were introduced during the third and fourth enforcement waves. Exhibit 2.17 compares the results of staccato enforcement efforts during the third wave of special enforcement with a group. As shown by the almost uniform height of the bars representing the ramp violation rates for the two groups of ramps, the two enforcement approaches seem to have had roughly the same impact on ramp violations. Both approaches caused a minor reduction in ramp violation rates (less than 10%) for the sample of low- and medium-violation ramps. Further investigation also showed that the two approaches had roughly identical residual impacts.

2.1.4 Impacts of Routine Enforcement

Control Ramps. At the same time that sample ramps in Los Angeles and San Diego were receiving different levels of special enforcement, the remaining ramps in these areas were exposed to the same levels of routine enforcement they had enjoyed prior to the study. Violation rates on six of these routinely enforced ramps were monitored throughout the study to provide a basis for interpreting the area-wide impacts of the special enforcement activities undertaken on other ramps. Exhibit 2.18 below summarizes the changes in violation rates on these six control ramps before and after special enforcement activities on other Los Angeles ramps.

Even though the six control ramps received no special enforcement, violation rates on five of these six ramps dropped significantly during the first year of the study as officers carried out special enforcement assignments on other Los Angeles ramps. Cumulative violation rates on the six control ramps dropped 20% over the first year of the study. Since violations were generally rising prior to the start of the study (see Reference 3), this reversal can most likely be interpreted as a by-product of special enforcement on other ramps. As drivers became aware of the highly visible enforcement actions taken on sample ramps throughout Los Angeles, violation rates dropped on routinely enforced ramps as well. Thus the benefits of the special enforcement program extended beyond the limits of those ramps receiving direct officer attention.

Mandated Routine Enforcement. Before this study began, nearly all enforcement actions taken on ramp bypass lanes were taken randomly in connection with the normal assortment of duties routinely undertaken by patrol officers. This routine approach to enforcement led to low citations and rising violation rates. Before the first wave of scheduled special enforcement activities undertaken in this study, the number of routine 21655.5 citations issued daily by each Southern Division CHP officer on a beat containing bypass lanes ranged from a low of 0.14 citations per officer in the West Valley Area to a high of 0.65 citations in the South Los Angeles Area. These citation rates were

Exhibit 2.17

RAMP VIOLATION REDUCTION
STACCATO ENFORCEMENT vs. STEADY ENFORCEMENT

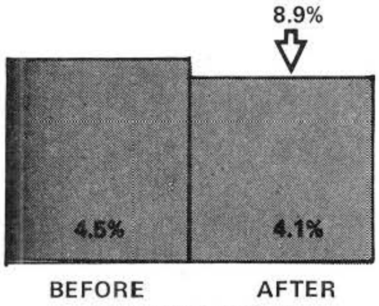
THIRD WAVE

TWO OFFICERS
TWO DAYS PER WEEK
ONE WEEK

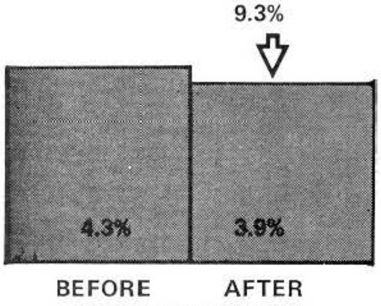
SECOND & THIRD WAVES

ONE OFFICER
ONE DAY PER WEEK
ONE MONTH

LOW VIOLATION RAMPS

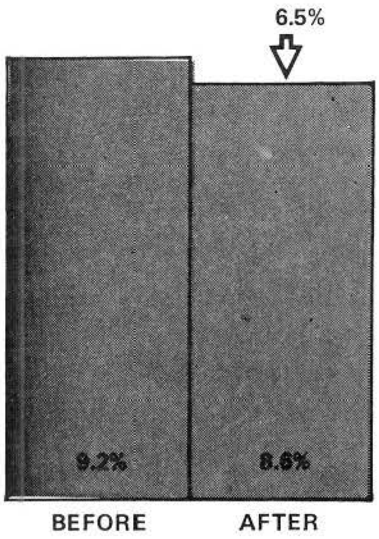


(6-RAMP SAMPLE)

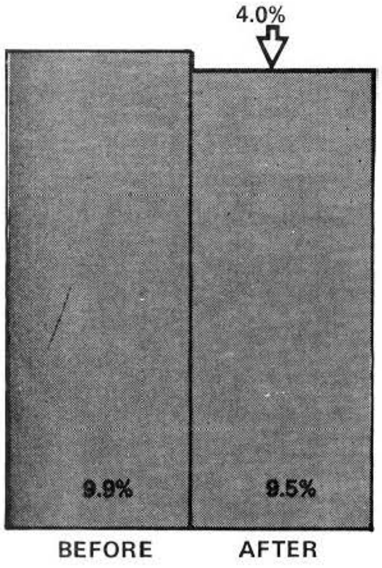


(11-RAMP SAMPLE)

MEDIUM VIOLATION RAMPS



(3-RAMP SAMPLE)



(3-RAMP SAMPLE)

Exhibit 2.18

VIOLATION RATES ON ROUTINELY ENFORCED RAMPS BEFORE AND AFTER SPECIAL ENFORCEMENT PROJECT

			RAMP VIOLATION RATES (%)		
Time	**Ramp**	**Route**	**Before First Special Enforcement Wave (April/June 1980)**	**After Third Special Enforcement Wave (May/June 1981)**	**Percent Change**
CONTROL RAMPS (Routine Enforcement Only)					
AM	Rosecrans	LA7	11.1	7.1	–36%
PM	Fairfax	LA10	15.7	12.0	–24%
AM	Cherry	LA91	18.3	19.4	+6%
PM	Century	LA7	7.4	5.2	–30%
AM	Laurel Canyon	LA101	7.2	5.4	–25%
AM	Spring	LA405	12.7	8.7	–32%
Average All Ramps			11.4	9.1	–20%

considerably lower than the rates reported by officers assigned to special enforcement activities, which ranged from five citations per day on ramps with low violation rates to 15 citations per day on ramps with high violation rates (see Section 2.1.6). To investigate the impact of increasing routine enforcement levels, two CHP command areas were asked to modify their approach to routine enforcement after eight months of the study had passed. Beginning in late November, 1980, the two CHP Areas, Santa Fe Springs and West Los Angeles, modified their approach to routine enforcement by instructing each officer assigned to a beat with ramp bypass lanes to spend ten minutes a day enforcing these lanes. Under this mandated approach to routine enforcement, officers were asked to vary their choice of ramps and enforcement times from day to day.

(1) Impact on Citation Rates. Exhibit 2.19 compares routine enforcement levels monitored during the four-week period from mid-April to mid-May 1981 with the levels recorded during the baseline period (May-June, 1980) for the two CHP Areas modifying their approach to routine enforcement, as well as for four other command areas in the CHP's Southern Division. Although the mandated approach to routine enforcement did not markedly increase the total number of 21655.5 citations issued by beat officers in the Santa Fe Springs and West L.A. Areas, routine citations in these areas did not suffer the decline experienced in other areas. In the case of Santa Fe Springs, the mandated approach to routine enforcement resulted in a slight increase over levels measured prior to special enforcement, while in West L.A., the numbers of routine citations issued dropped slightly below pre-enforcement levels. As a result, the number of citations issued per available officer in the two areas remained relatively unchanged at 0.40 citations per officer per day. These citations tended to be concentrated on one or two ramps in each area.

It is likely that the mandated approach to routine enforcement adopted in Santa Fe Springs and West L.A. had more of an impact on citation levels than is apparent from a simple before-after comparison. Exhibit 2.16 also shows that in other Southern Division Areas retaining the traditional approach to routine enforcement, the number of 21655.5 citations issued routinely dropped markedly over the first year of special enforcement. In one area (South L.A.) some portion of this drop can be traced to the retirement of an officer who had undertaken the single-handed enforcement of all the area's bypass lanes. In the other three control areas, however, the decline in routine enforcement activities parallelled the decline in violation rates accompanying special enforcement assignments. As periods of special enforcement discouraged violators, the opportunities for routine enforcement dropped, and the combined daily number of routine citations issued by officers in the four control areas dropped from 0.40 citations per officer during the baseline period to 0.22 citations per officer after one year of special enforcement activities. It can be inferred, therefore, that the mandated approach to routine enforcement (ten minutes per day per officer) adopted by Santa Fe Springs and West L.A. kept the routine enforcement levels in these areas from undergoing a similar slide. In addition to sustaining the level of citations, moreover, the mandated approach also increased the amount of in-view officer deployment in the vicinity of ramp bypass lanes.

Exhibit 2.19

ROUTINE ENFORCEMENT LEVELS BEFORE AND AFTER A YEAR OF SPECIAL ENFORCEMENT ACTIVITIES

	Areas Mandating Routine Enforcement*			**Areas Continuing Routine Enforcement⁺**				
Average Daily Statistics	**Santa Fe Springs**	**West L.A.**	**Total**	**Glendale**	**Central L.A.**	**South L.A.**	**West Valley**	**Total**
ROUTINE 21655.5 CITATIONS								
Before Special Enforcement (May/June, 1980)	3.60	5.49	9.09	2.87	12.42	5.65	1.92	22.86
After Third Wave of Special Enforcement (May 1981)	4.95	4.44	9.39	0	11.33	0.49	1.14	12.96
CITATIONS PER RAMP								
Before Special Enforcement (May/June 1980)	0.15	0.66	0.27	0.36	0.50	0.71	0.12	0.40
After Third Wave of Special Enforcement (May 1981)	0.20	0.30	0.23	0	0.45	0.03	0.07	0.19
CITATIONS PER OFFICER								
Before Special Enforcement (May/June 1980)	0.35	0.42	0.39	0.23	0.37	0.65	0.14	0.38
After Third Wave of Special Enforcement (May 1981)	0.49	0.34	0.40	0	0.34	0.06	0.08	0.22

*Each beat officer spends 10 minutes per day on ramp enforcement at a ramp and time selected by the officer.

⁺Officers enforce ramps randomly in course of other duties.

(2) Impact on Violation Rates. Exhibit 2.20 tabulates violation rates on ramps exposed to mandated routine enforcement activities (but not to special enforcement activities) in the Santa Fe Springs and West L.A. CHP Areas. The exhibit compares violation rates prior to the study with rates recorded one year after the start of the study (and six months after the initiation of a mandated program of routine enforcement) on five sample ramps in each CHP Area. Violation rates on the sample of five Santa Fe Springs ramps dropped 14.5%[4] over this period, while rates in West L.A. dropped 13.2%. As Exhibit 2.15 has shown, however, violation rates on routinely enforced ramps in other areas dropped an average of 20% over the same period. Since violation rates on ramps in the two CHP Areas modifying their routine enforcement procedures did not decline as much as violation rates on routinely enforced control ramps in other CHP Areas, it was concluded that the mandated approach to routine enforcement had no impact on ramp violation rates.

(3) Reflections on Routine Enforcement. Reliance on routine enforcement has historically resulted in low citation levels on ramp bypass lanes and corresponding increases in ramp violation rates. Attempts to increase routine enforcement levels in two CHP Areas by asking each officer to spend 10 minutes a day on ramp enforcement activities did not affect either the number of citations issued or the number of violators appreciably. One important reason for the ineffectiveness of routine approaches to ramp enforcement may lie in the attitudes of the officers themselves. Many officers do not enjoy enforcing HOV restrictions on ramp bypass lanes. Although there are enough violators available so that a relatively modest amount of officer time and effort can generate a large number of 21655.5 citations, most officers (and their superiors) do not consider these citations to be nearly as important as citations for more serious offenses such as speeding, drunken driving, and tailgating. These offenses are classified as primary collision factors which contribute directly to the accident rate, and understandably command a higher priority in the mind of the beat officer undertaking routine enforcement.

In addition, several officers and their superiors noted that "...officers take more verbal abuse for diamond lane citations than for any other form of enforcement activity." It is only natural that the enthusiasm of an officer for ramp enforcement will flag as this abuse sinks in with every irate violator. Moreover, there is the possibility that a formal complaint will be lodged against the officer himself, and ramp enforcement duty brings the officer face-to-face both with more violators and with more irate violators than almost any other form of enforcement. Several officers said that they volunteered for special ramp enforcement assignments during the current study only because the incentive of overtime pay was available.

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[4] In the case of Santa Fe Springs, the decline in violation rates was not statistically significant (at the 95% level of significance).

Exhibit 2.20

VIOLATION RATES ON RAMPS WITH MANDATED ROUTINE ENFORCEMENT

			RAMP VIOLATION RATE (%)		
Time	**Ramp**	**Route**	**Baseline (April/June 1980)**	**After Six Months of Mandated Routine Enforcement (May/July 1981)**	**Percent Change**
SANTA FE SPRINGS RAMPS (Mandated Routine Enforcement Only)					
AM	Del Amo	LA 605	9.2	4.9	−46.7%
AM	Whittier WB	LA 605	4.0	2.5	−37.5
PM	Slauson	LA 605	6.5	14.1	+116.9
PM	Alondra	LA 605	6.4	4.6	−28.1
PM	Studebaker	LA 605	6.5	8.4	+29.2
Average All Ramps			6.9	5.9	−14.5%
WEST LA RAMPS (Mandated Routine Enforcement Only)					
AM	Century EB	LA 405	9.3	8.0	−14.0%
AM	Century WB	LA 405	18.6	19.4	+4.3
PM	Manchester	LA 405	19.9	16.5	−17.1
PM	National	LA 405	7.1	5.1	−28.2
AM	Sunset	LA 405	7.5	7.3	−2.7
Average All Ramps			14.4	12.5	−13.2%

Other reasons why mandated routine enforcement proved ineffective include the difficulty of targeting such enforcement and the difference between routine and special enforcement tactics employed by some officers. Officers naturally tended to concentrate their attentions on a few favorite ramps which were particularly easy to observe and enforce, leaving many ramps unenforced. Moreover, some officers charged with enforcing ramps for 10 minutes of each day consciously avoided the stationary enforcement tactics which had proven successful in special enforcement stints. Rather, they chose to honor their commitment by pursuing violators observed while patrolling the freeway itself and issuing citations at a point well removed from the scene of the crime. The officers reasoned that if they stopped on the ramp itself to issue a ticket, more violators would appear who would have to be dealt with (or ignored, to the chagrin of the ticketed violator and law-abiding motorists) causing the time devoted to the unpleasant activity of ramp enforcement to stretch beyond the 10-minute commitment.

(4) Summary. As special enforcement activities progressed and the number of violations dropped, opportunities for routine enforcement declined and the number of routinely issued citations dropped in most CHP Areas. In the two areas where officers were instructed to spend ten minutes each day on routine ramp enforcement, routine citation rates did not drop, but neither did they rise appreciably. Moreover, this mandated approach to routine enforcement had no measurable impact on violation rates.

The possibility of increasing the level of mandated routine enforcement activity still further (i.e., by requiring officers to spend ten minutes of each hour on ramp enforcement) was considered but rejected. Any further increase would have demanded personnel commitments nearly equal to those required by special enforcement approaches which were easier to direct and control, and which had already proven effective in reducing violation rates.

2.1.5 Bail Schedules

Bail schedules for 21655.5 violations vary considerably between municipalities. As a consequence, the penalty for using a specific bypass lane illegally may differ widely from the penalty paid for the same violation on adjacent ramps on the same freeway. On the section of the San Diego Freeway (LA Route 405) covered by the South Los Angeles CHP Area, the bail for occupancy violations levied by the South East South court is $23.50, while the bail for the same offense under the Inglewood jurisdiction is more than double that amount ($49.50). Exhibit 2.21 displays the bail schedules by municipalities within each CHP area.

To determine whether the widely varying bail schedules had a quantifiable impact on violation rates, an attempt was made to find sets of ramps that had similar enforcement histories, use patterns, and HOV lane installation dates, but widely different bail schedules.

Exhibit 2.21

OCCUPANCY CITATION (21655.5) BAIL SCHEDULES BY MUNICIPALITIES WITHIN EACH CHP AREA

CHP AREAS	MUNICIPAL COURTS	BAIL SCHEDULE
SOUTHERN DIVISION		
GLENDALE	Glendale	$31.00
	Burbank	$49.00
	Pasadena	$28.50
	Los Angeles (S. Hill Street)	$49.50
	Van Nuys	$28.50
SANTA FE SPRINGS	Downey	$29.00
	Los Cerritos (Bellflower)	$49.00
	Rio Hondo (El Monte)	$31.50
	Whittier	$52.00
CENTRAL LOS ANGELES	Los Angeles (S. Hill Street)	$24.50
WEST LOS ANGELES	Inglewood	$49.50 (2nd offense—$54.50, 3rd or more—$67.50)
	West Los Angeles	$28.50
SOUTH LOS ANGELES	Compton	$49.50
	South East South	$23.50
	South East North	$28.50
		(2nd offense—$36.50,
	San Pedro	3rd or more—$41.50)
	Inglewood	$49.50
		(2nd offense—$54.50,
		3rd or more—$67.50)
	South Bay	$26.50
		(2nd offense—$36.50)
WEST VALLEY	Malibu	$47.00
	Van Nuys	$28.50
EAST LOS ANGELES	Alhambra	$28.00
	Compton	$28.50
	East Los Angeles	$28.50
	San Antonio — South East	$28.50
	South Gate — South East	$23.50
BALDWIN PARK	Rio Hondo (El Monte)	$31.50
	Alhambra	$28.00
BORDER DIVISION		
WESTMINSTER	Uniform rate for all municipalities	$25.00
SANTA ANA		$25.00
SAN DIEGO		$13.50
EL CAJON		$13.50
GOLDEN GATE DIVISION		
SAN FRANCISCO (SF/Oakland Bay Bridge)		$26.50
SAN JOSE (Guadalupe on-ramp)		$26.50
HAYWARD (Alameda 580)		$26.00
MARIN (Marin 101)		$21.00

Exhibit 2.22 aggregates ramp violation rates (before and after special enforcement activities) by municipalities within the Santa Fe Springs and Glendale areas. Since violation rates on bypass lanes have been found to increase with the length of time since the HOV lanes were installed, only ramps with similar operation histories within each area were included in the comparison. At the start of the study, ramps in the Santa Fe Springs Area has been operating for 27 months, while ramps in the Glendale Area had been operating for 33 months.

The tabulated results seem to suggest that bail schedules have little impact on violation levels. Prior to special enforcement activities, ramp violation rates were found to be slightly lower in municipalities with higher bail schedules than other nearby municipalities. The difference in mean ramp violation rates between municipalities with high and low bail schedules was found to be statistically significant (at the 95% level) in the Glendale CHP Area, but not in the Santa Fe Springs Area. Following special enforcement, no significant differences were found in other CHP Areas between violation rates in jurisdictions with markedly different bail schedules. Since the number of ramps in each sample is small and the mean ramp violation rates are relatively low, the conclusion that bail schedules have little impact on violation rates must be viewed with caution. On a statewide level, ramp violation rates are lowest in the San Diego Area, which also has the lowest bail schedule for offenses ($13.50 per offense).

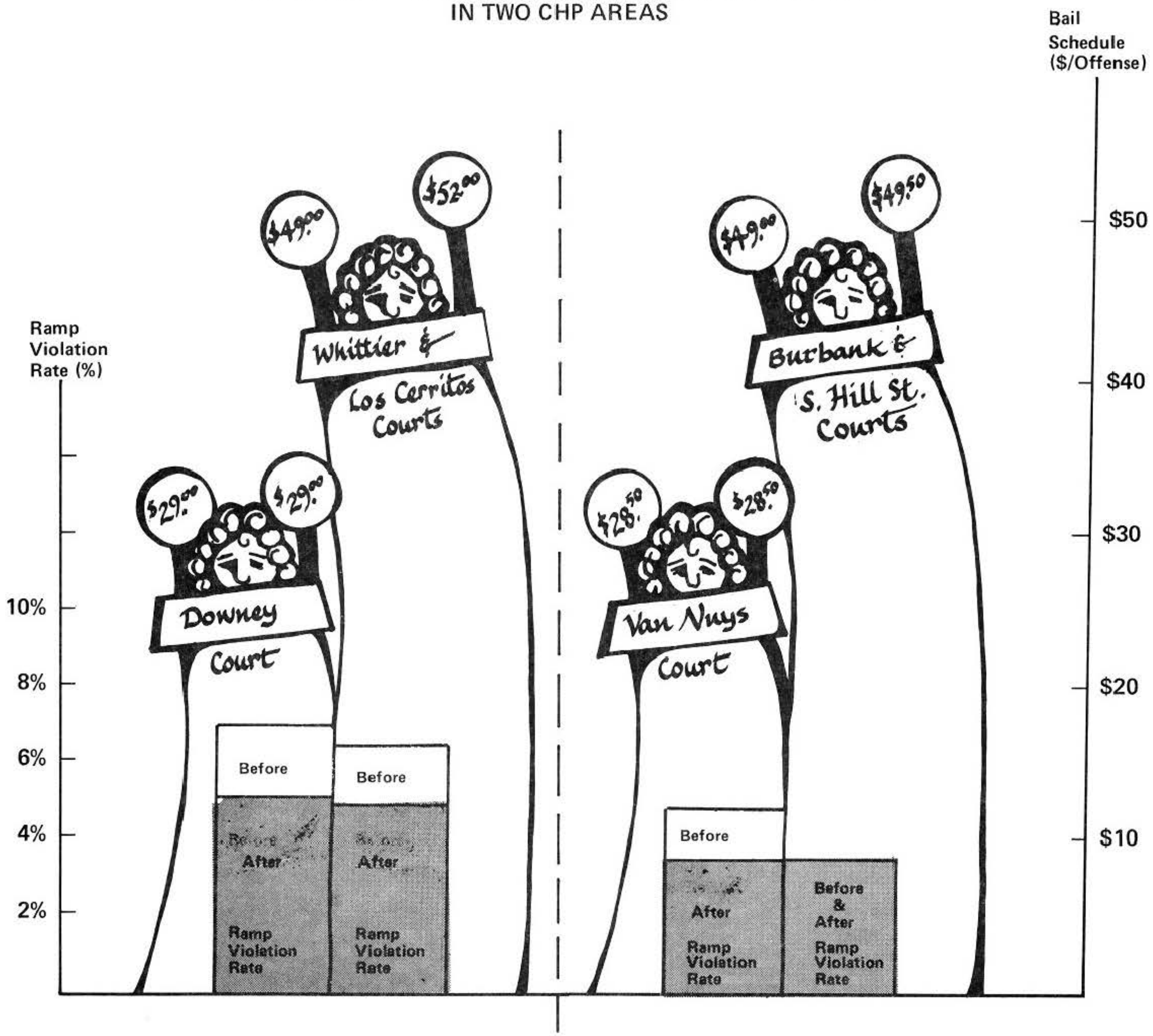
2.1.6 Citations and Violations

Citations per Officer. To provide additional insight into the impact of enforcement on violation rates, the CHP compiled and tabulated data on the number of citations given at each bypass ramp and mainline HOV lane in California during the course of the study. Exhibit 2.23 lists the average number of 21655.5 citations issued daily on the study ramps in Los Angeles and San Diego aggregated by the historical violation levels and enforcement visibility. As would be expected, the number of tickets given was heavily dependent on the ramp's violation history. On ramps with high historical violation rates (ramp violation rates in excess of 12%) each CHP officer issued an average of 15.2 code 21655.5 citations per peak period. This average fell to 5.7 citations per period on ramps with historically low violation rates (rates under 6.5%). Officers enforcing ramps with historical violation rates between 6.5% and 12% issued an average of 7.6 occupancy citations per peak period.

Exhibit 2.23 also shows, not surprisingly, that officers had a little more success in issuing citations on ramps whose geometry hid them from view of oncoming motorists. On ramps where enforcement took place in full view of motorists entering the ramp, officers issued an average of 8 citations per day. On ramps where enforcement activities were not visible to the oncomping motorist, or where the motorist had to make some progress along the ramp before seeing the officer, the average number of citations given out during each peak period rose

Exhibit 2.22

FINES AND VIOLATION RATES FOR COMPARABLE RAMPS IN TWO CHP AREAS



	SANTA FE SPRINGS CHP AREA		GLENDALE CHP AREA	
	Downey Courts	Whittier and Los Cerritos Courts	Van Nuys Court	Burbank and South Hill St. Courts
Bail Schedules	$29.00	Over $49.00	$28.50	Over $49.00
No. of Sample Ramps	3	10	3	5
Mean Ramp Violation Rates				
Before Enforcement	7.0%	6.5%	4.6%	3.3%
After Enforcement	5.0%	4.9%	3.5%	3.3%
Overall % Change	28.6% drop	24.6% drop	23.9% drop	0%

Exhibit 2.23

DAILY OCCUPANCY VIOLATION CITATION RATES DURING EACH SPECIAL ENFORCEMENT WAVE BY HISTORICAL VIOLATION LEVELS AND OFFICER VISIBILITY

	Daily Citation Rates (Tickets/Officer)				
	1st Wave	2nd Wave	3rd Wave	4th Wave	Average
HISTORICAL VIOLATION LEVELS					
High	15.9	15.2	15.8	14.1	15.2
Medium	9.7	6.5	7.1	6.7	7.6
Low	5.3	5.3	6.8	5.9	5.7
OFFICER VISIBILITY					
Visible	8.5	8.5	7.6	7.5	8.0
Queue Dependent	10.8	8.7	13.7	11.1	11.1
Not Visible	13.0	12.4	11.0	10.8	11.9
AVERAGE	10.9	10.0	10.7	10.1	10.5

slightly, to 11 citations per officer. Although fewer citations were given on ramps classified as visible, enforcement efforts on these ramps were found to be just as effective in reducing violations as enforcement on ramps where enforcement was not visible to the oncoming motorist (see Section 3.1.1).

Correlating Citations and Violations. In an effort to understand the relationship between ticketing activity and ramp violation rates, the total number of tickets given on each sample ramp during the four waves of enforcement was compared with the average reduction in daily violations observed on that ramp. Exhibit 2.24 plots the reduction in daily violations (computed by comparing pre-first wave and post-fourth wave violations) with the total number of citations issued over the four enforcement waves. This relationship conforms reasonably well ($r = -.75$) to a log-linear relationship of the form

$$y = b + m\,(\ln x)$$

where y = change in violations
x = total number of citations
b = correlation constant = 187.43
m = correlation coefficient = -51.04

The exponential nature of this relationship reflects the saturating effect of additional enforcement effort (i.e., the law of diminishing returns).

2.1.7 Impacts of Ramp Enforcement on Traffic Flow

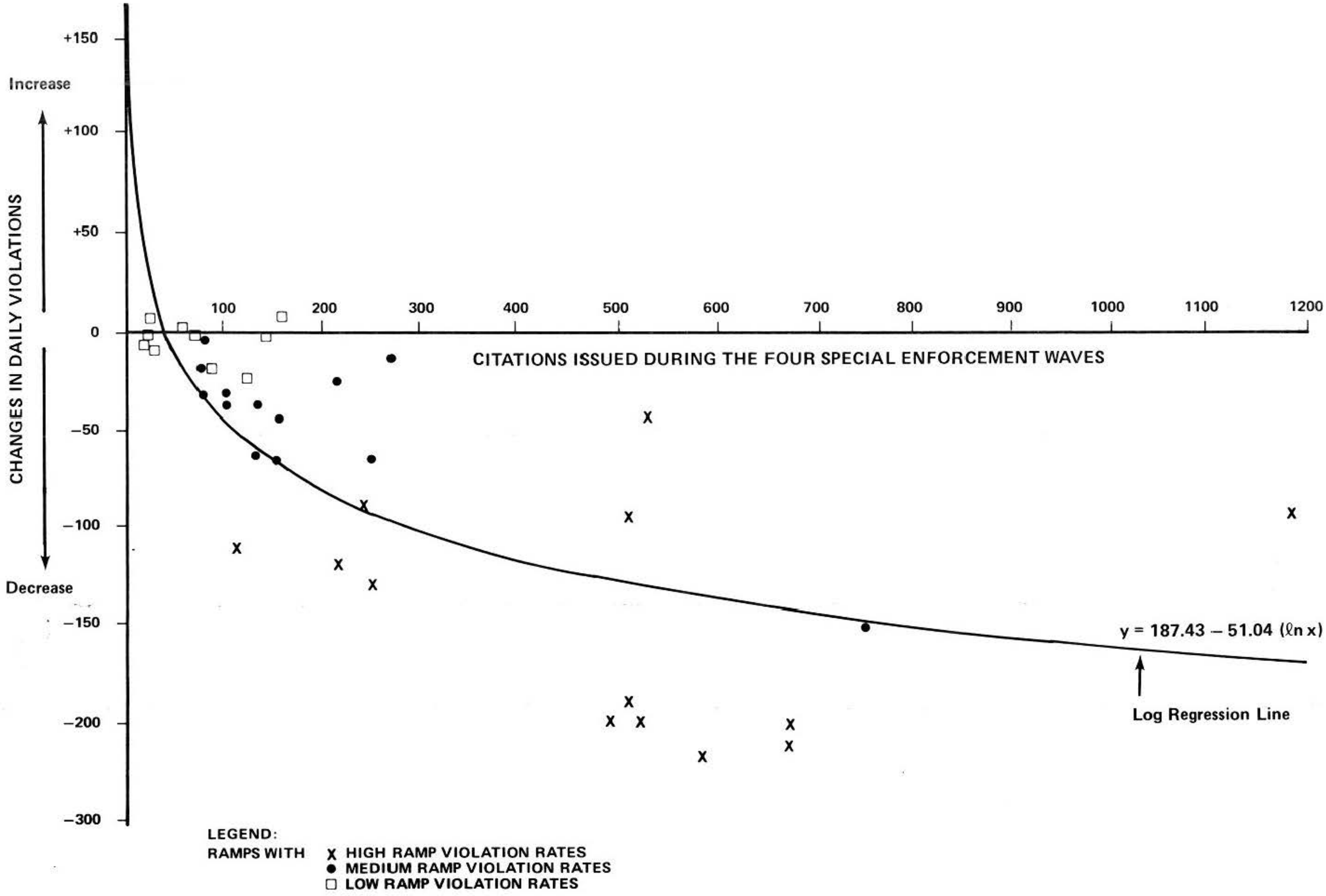
In addition to reducing violation rates, enforcement actions taken by highway patrol officers on ramp meter bypass lanes can have a measurable impact on traffic flow in the vicinity of those projects. As more and more tickets are issued on bypass lanes, former violators join the metered queue, causing the delays experienced by all vehicles in the queue to increase. Moreover, the ticketing activity itself can distract drivers on adjacent freeway lanes, leading to additional traffic congestion.

Impact of Enforcement on Ramp Delays. The initial wave of special ramp enforcement activities undertaken during the summer of 1980 had a marked impact on violation rates. On a sample of thirty-three Los Angeles ramps receiving special enforcement, the average ramp violation rate dropped from 12.4% to 8.6% while the average lane violation rate dropped from 37.7% to 29.8%. As more and more drivers chose to join the meter queue rather than use the bypass lane illegally, the length of these queues grew, causing the delay encountered by drivers entering the freeways to grow as well.

Prior to the first wave of enforcement, the average delay encountered by autos entering Los Angeles freeways through thirty-three sample ramps was 45 seconds. After the initial wave of special

Exhibit 2.24

TOTAL CITATIONS ISSUED DURING THE FOUR SPECIAL ENFORCEMENT WAVES VS. CHANGES IN DAILY VIOLATIONS BETWEEN PRE-ENFORCEMENT AND POST-FOURTH WAVE



enforcement, this delay increased to 54 seconds. A breakdown of the delays encountered on thrity-three Los Angeles ramps before and after the first enforcement wave may be found in Appendix F. On nineteen of the thirty-three ramps, statistically significant increases in delays were observed, while ten showed no significant change, and only four ramps showed a statistically significant decrease in the delay encountered in entering the freeway. Of those ramps experiencing a decrease in delay, one (Woodman Ave. on LA 101) had its metering rates changed during the enforcement phase to expedite queue movement, while two others (Coldwater Canyon on LA 101 and Vernon Ave. on LA 11) had experienced a loss of over 100 vehicles during the peak hour, presumably reflecting traffic diversions to avoid enforcement or minimize delay.

Impact of Ramp Enforcement on Freeway Traffic. The geometric configuration of most on-ramps leads CHP officers to enforce preferential lane provisions near the nose of the ramps, where the ramp joins the freeway (see Exhibit 2.25). When this enforcement activity takes place in full view of the mainline freeway traffic, it can cause gawking and possibly contribute to additional freeway congestion. To determine the extent to which ramp enforcement activities affected mainline traffic flow, the average freeway speeds upstream and downstream from four sample on-ramps were monitored on special enforcement days. These speeds were monitored at 5-minute intervals using the electronic detectors installed by CALTRANS as part of the 42-mile surveillence loop on the Santa Monica, San Diego, and Harbor Freeways. Speed data accumulated on special enforcement days were compared with corresponding data recorded on days when no enforcement was present. The results of this comparison, which appear in Exhibits 2.26 and 2.27, confirm the hypothesis that certain ramp enforcement activities have a slowing effect on freeway traffic flow, and provide a quantitative estimate of the magnitude of that effect.

Freeway speeds were monitored in the vicinity of the following four on-ramps:

Ramp	Freeway	General Enforcement Location
Manning	LA 10	Freeway shoulder
Florence	LA 11	Freeway shoulder
Inglewood	LA 405	Freeway shoulder
Venice	LA 10	Collector road

On days when CHP officers were enforcing the ramp bypass lanes, the average freeway speed upstream from all of the sample ramps was significantly lower than on days when there was no enforcement. On three of the four sample ramps, moreover, no significant difference was found in the average speed measured downstream after freeway traffic had passed the on-ramp. The only significant difference in the downstream freeway speed was found on the Florence ramp feeding into Harbor Freeway, where traffic flow was slightly faster on special enforcement days. Apparently the presence of the CHP near the nose of the ramp caused freeway drivers approaching the ramp to slow down, resulting in additional congestion and slower speeds upstream from the ramps. Drivers picked up speed as they drove past the ramps, returning the downstream freeway flow to normal.

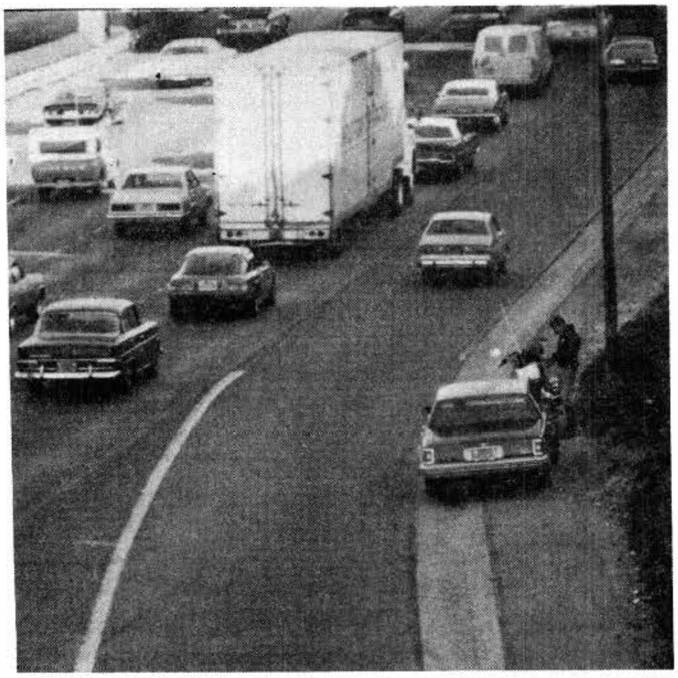
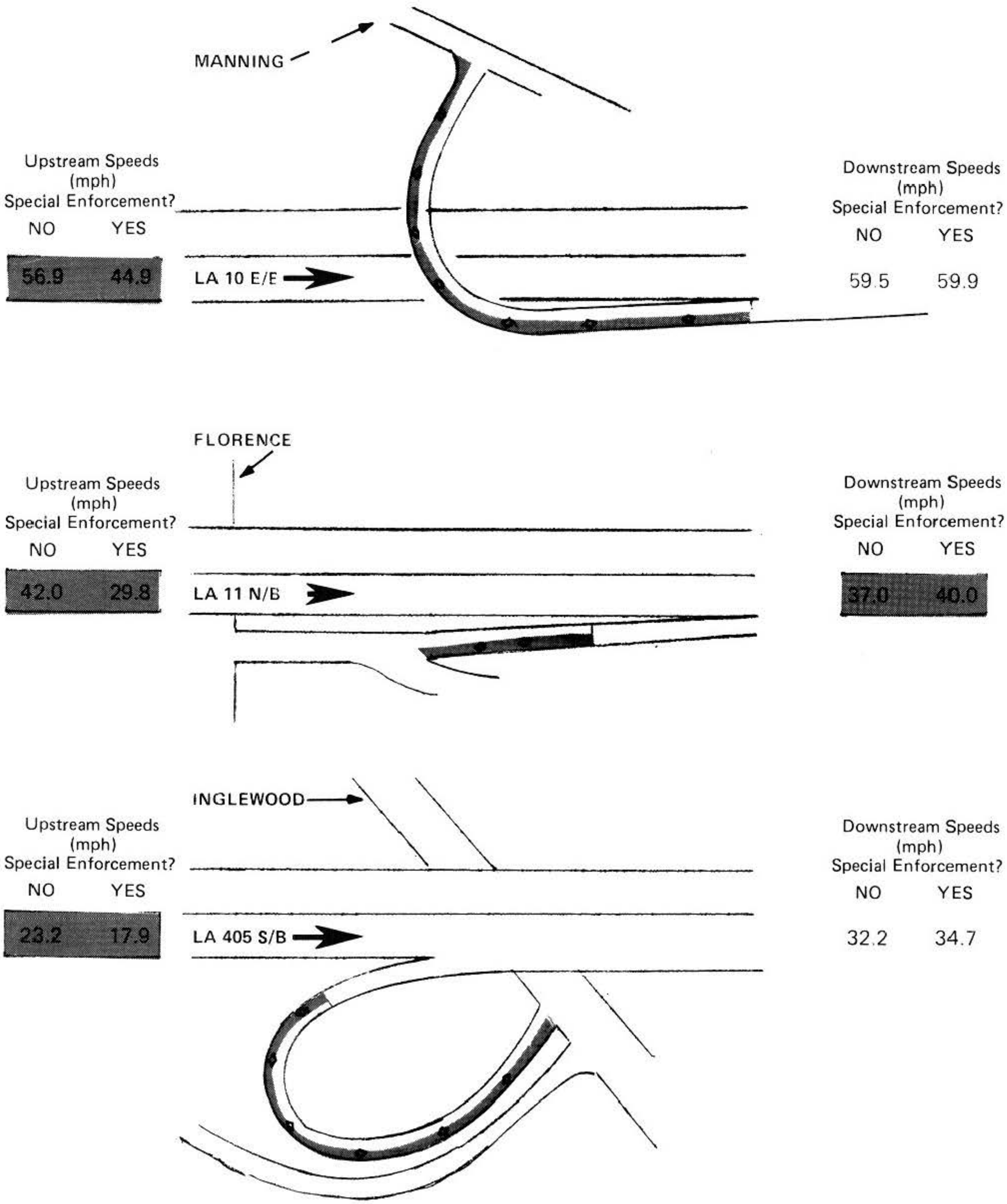


EXHIBIT 2.25

Photograph of Ramp Enforcement Activity with Congested Flow Conditions on Adjacent Freeway

EXHIBIT 2.26

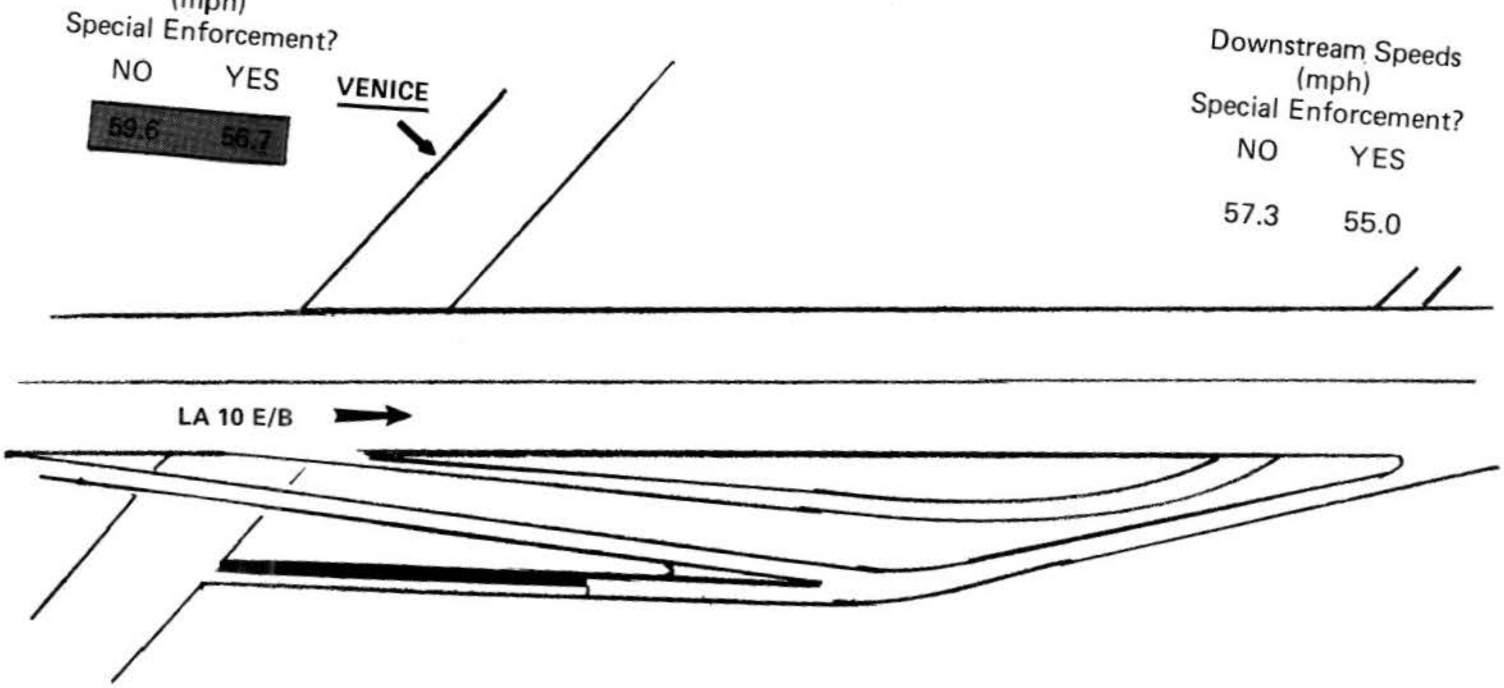
AVERAGE FREEWAY SPEEDS
With and Without Special Enforcement
at Side of Freeway



NOTES: Speed samples represent 132 observations on eleven enforcement days
58 observations on five non-enforcement days at Florence and Inglewood
79 observations on seven non-enforcement days at Manning

▨ Indicates a statistically significant difference.

EXHIBIT 2.27
AVERAGE FREEWAY SPEEDS
With and Without Special Enforcement on Frontage Road



NOTES: Speed samples represent 142 observations on twelve enforcement days
93 observations on eight non-enforcement days

■ Indicates a statistically significant difference.

The decline in mean freeway speed upstream from the four sample ramps on days when CHP officers were present ranged from a drop of roughly 3 mph near the Venice ramp to over 12 mph on the Florence ramp. On the Venice ramp, enforcement activities took place on a collector road removed from the mainline freeway flow (see sketch in Exhibit 2.27), and the resulting impact on freeway flow was minimal. The drop in freeway speed was more pronounced upstream from the remaining three ramps, each of which was enforced in full view of commuter traffic. On these three ramps, the traffic disruption resulting from special enforcement caused a delay ranging from 58 to 111 vehicle nours per day (see Section 6.1.3).

2.2 MAINLINE HOV LANES AND THE SAN FRANCISCO/OAKLAND BAY BRIDGE'

2.2.1 Historical Enforcement Levels

Exhibit 2.28 below lists historical enforcement levels for the three mainline HOV lanes considered in this study, as well as the priority lane on the San Francisco/Oakland Bay Bridge. Lane violation rates are used as the primary measurement of HOV violations. The lane violation rate was chosen as the appropriate measure because it is not heavily dependent on location (see Study Design, page 4-8). The project's violation rate is much lower than the lane violation rate. In all cases, the violators comprise less than 2% of the total freeway flow.

As shown in Exhibit 2.28, historical citation rates for the mainline HOV lanes have been considerably higher than for the bypass ramps and range from a low of four tickets per weekday (Alameda 580) to 14 tickets per weekday (San Bernardino Busway). Citation rates have been dropping in the last few years for each of these projects, as can be seen by comparing pre-1980 citation rates with 1980 pre-enforcement citation rates. These declines have generally been gradual on all projects except Marin 101. A change in deployment strategy during the first five months of 1980 caused enforcement levels on Marin 101 to be unusually light just prior to the initial wave of special enforcement activities undertaken as part of this study. Lane violation rates have generally risen only slightly since the projects began carpool operation. The exception is Alameda 580, where violation rates have doubled since the carpool lanes were installed.

2.2.2 Enforcement Levels and Tactics

The first wave of special enforcement activities took place on mainline HOV lanes early in May 1980. Periods of special enforcement were limited to two weeks so that post-enforcement measurements could be made in advance of summer vacation. Exhibit 2.29 summarizes the special enforcement activities for the three mainline HOV lanes: Marin 101, Alameda 580, and the San Bernardino Busway. Between two and four

Exhibit 2.28

HISTORICAL ENFORCEMENT LEVELS ON MAINLINE HOV LANES AND SPECIAL BRIDGE LANES

	PRE-ENFORCEMENT DATA (1980)		HISTORICAL DATA (Before 1980)	
Project	**Lane Violation Rate***	**Citation Rate (per weekday)**	**Lane Violation Rate* (at time of carpool lane opening)**	**Citation Rate (per weekday)**
MAINLINE HOV LANES:				
Marin 101	21.5%	2.93	15%	11.66
Alameda 580	30.5%	2.54	15%	4.00
San Bernardino Busway	8.8%	10.83	7%	14.37
SPECIAL BRIDGE LANES:				
San Francisco/ Oakland Bay Bridge	5.4%	0.61	6%	2.36**

*The lane violation rate is defined as the total number of violators divided by the total non-bus vehicles in the HOV lane.

**Includes I-280 citations.

Exhibit 2.29

SCHEDULE OF SPECIAL ENFORCEMENT ACTIVITIES
Mainline HOV Lanes and SFOBB

Route	CHP Area	Wave	Additional Officers		Days/Week	Duration (weeks)	Start/Finish Dates	Routine Enforcement
			AM	PM				
Marin 101 (3.7 mi. concurrent lane)	Marin	1 2	0 0	2 0-1	4 4	2 4	May 5/May 16 1980 Nov. 3/Nov. 28 1980	Two to three officers during PM peak period five days a week enforcing primarily HOV violations. Recently, number of officers increased to four. 1.08 officers per project mi./weekday (PM).
Alameda 580 (3.5 mi. separate lane)	Hayward	1 2	2 0	2 2	2 4	2 4	May 5/May 16 1980 Jan. 5/Jan. 30 1981	One or two officers on normal beat. Selective enforcement not common. 0.29 officers per project mi. per weekday (PM).
San Bernardino Freeway (4 mi. separated lane 7 mi. median lane)	East L.A.	1 2	4 4	4 0	2 2	2 4	Apr. 28/May 9 1980 Mar. 4/Mar. 27 1981	Four regular enforcement units in AM, six in PM. Program of selective enforcement of HOV lane violations ended a few years ago. 0.86 officers per project mile per weekday (PM).
	Baldwin Park	1 2	2 2	0 0	2 2	2 4	Apr. 28/May 9 1980 Mar. 4/Mar. 27 1981	
San Francisco/Oakland Bay Bridge (0.7 mi. toll lane)	San Francisco	1 2 3	2 2 4	0 0 0	2 4 5	4 6 1	Jul. 14/Aug. 8 1980 Oct. 20/Nov. 28 1980 Mar. 30/Apr. 3 1981	Some enforcement by officers driving through. Selective enforcement about once a month by two officers for one or two days. 0.26 officers per project mi. per weekday (AM).

additional officers were assigned to each project for two to four days per week during each two-week enforcement period. The second wave of enforcement began at different times between late 1980 and early 1981. The duration of enforcement was lengthened to four weeks but the number of special enforcement days per week remained the same. Special enforcement was limited to a single direction of travel during the peak commuting period. Some projects were enforced only in the morning, while others were enforced only during the evening peak.

Marin 101. Preferential lane restrictions on Marin 101 are generally enforced using motorcycles, because of the lack of a median lane and the limited amount of shoulder space. Enforcing officers need to guide violators across three lanes of traffic to a narrow eight-foot shoulder. During the winter rains, when motorcycle use is hazardous, a patrol car is parked in a highly visible position on the freeway shoulder to discourage violators, slow down traffic, and respond to accident calls. Marin 101 currently has the highest level of on-going enforcement of any of the HOV projects studied. Currently, four motorcycles are routinely assigned specifically to enforce the carpool lane during the evening peak.

Alameda 580. Alameda 580 is most often enforced by patrol cars. Officers on Alameda 580 pull violators over to a fairly wide shoulder with a dirt median. Routine enforcement usually consists of one unit on a normal beat during the morning and afternoon peaks. Special enforcement is used infrequently.

The San Bernardino Busway. The San Bernardino Busway is enforced differently on the two distinct sections of the freeway. On the western section of the busway, where the busway is completely separated from general traffic by a physical barrier, enforcement is minimal because violation rates are low, and the limited access makes it difficult to patrol efficiently.

On the eastern section of the busway, where the busway is separated from general traffic by a median strip, violations are currently enforced exclusively by officers on routine patrol. During the less congested periods, the CHP will normally patrol in the traffic lane adjacent to the buffer lane. Violators are pulled over into the buffer lane. During the peak periods of traffic flow, officers will station themselves in the buffer lane and monitor both mainline and busway traffic. Special enforcement units (S.E.U.s), normally used for truck enforcement, were used during the study for HOV lane enforcement. Prior to the study, S.E.U.s had also been used periodically to enforce the HOV lane.

Special enforcement activities during the study normally took place on the buffer shoulder with officers pulling over violators, often detaining more than one vehicle at a time. At one point during the first wave of special enforcement, as many as ten violators were "stacked" at a single location on the buffer strip awaiting citations.

During the first wave of special enforcement, roadside observers noticed that the special enforcement activities disrupted traffic. Different enforcement procedures were tried during the second wave of enforcement in order to minimize "rubbernecking" and the resulting breakdowns in traffic flow during congested periods. The following four policies were adopted:

- Avoid stacking - No more than one car waiting (beyond the vehicle being cited).

- Avoid bunching - Each officer works individually, separated from other officers by at least 1/4 mile.

- Release into Busway - Release cited motorist into busway rather than mainline lanes.

- Limited Pursuit - Apprehend violators from busway or closest mainline lane only. Avoid stopping mainline lanes whenever possible.

Traffic speeds were recorded in the general traffic lanes before and during the special enforcement wave. The results are presented later in section 2.2.4.

San Francisco/Oakland Bay Bridge. The first wave of special enforcement activities on the San Francisco/Oakland Bay Bridge (SFOBB) took place between mid-July and mid-August 1980. Two motorcycle officers were assigned to patrol the toll booth area two days each week throughout the one-month period. During the second wave which took place in October and November of 1980, the intensity and duration of enforcement was increased. A third wave of enforcement started in late March 1981 and lasted only one week but involved up to four officers for five weekdays.

Motorcycles have historically been used for enforcement on the Bay Bridge because of the absence of ample shoulder lanes. Enforcing officers tend to wait at the shoulder for violators to pass through the toll booth. The violators are pursued through the metering signals and pulled off on the shoulder before reaching the bridge entrance. The motorcycle officer then returns to his position by driving along the shoulder against traffic. Alternatively, a motorcycle or patrol car officer may set out cones near the carpool lanes and wave violators into the refuge area created by the cones. This technique produces more citations per officer hour, but consumes valuable space on the bridge approach and requires the officer to pull over cars that are moving at a reasonable speed past the empty carpool toll booths. The first approach, requiring pursuit, was used in the first enforcement wave, and the latter during the second and third waves.

Historically, relatively few tickets for occupancy violations have been written by officers that are on their normal beat. More commonly, the Bridge manager will ask the CHP to enforce the carpool toll lanes when the number of violators appears to be rising. The bridge is then usually hit hard for a few days until the violation rate is lowered.

2.2.3 Impact of Violation Rates

Exhibit 2.30 summarizes violation rates for each of the projects before, during and after each wave of special enforcement. A detailed discussion of the results of special enforcement and plots of violation rates are presented below for each of the mainlines and the San Francisco/Oakland Bay Bridge.

Alameda 580. The changes in violation rates and enforcement levels during the evening peak period on Alameda 580 over the course of the study are presented graphically in Exhibit 2.31. Violation rates dropped sharply and remained low for one month after the first wave of special enforcement but gradually began to rise until stabilizing at a slightly higher "base" level. The second wave of enforcement, though twice as long and with the same number of officers and days per week, did not reduce the violation rate as much as in the first wave. The violation rate also rose more quickly after the second wave, reaching the pre-enforcement level within two months and leveling off at an even higher level. The gradual rise of the violation rate from the historical (pre-study) rate of 32% to the last count of 43% may have been due in some part ot the adverse publicity regarding the diamond lanes on Alameda 580. In April of 1980, an advisory question on the local ballot resulted in 80% of the voters proposing that the diamond lanes be eliminated. Later in 1980, the newspapers extensively covered CALTRANS' public meetings on future diamond lane plans and attempts by legislators to have the diamond lanes removed. The adverse publicity may have encouraged more people to disregard the diamond lane restrictions. Furthermore, the CHP reduced routine enforcement levels during the evening peak and concentrated on the AM peak hours after the second wave of enforcement, cutting the citation rate almost in half. During the AM peak, violation rates decreased little during the first wave of special enforcement but dropped afterward from 26% to 11% in a week. This lagging effect was noticed in several of the projects and may have been due to a gradual buildup of driver caution as they became aware of special enforcement activities.

San Bernardino Busway. Violation rates on the San Bernardino Busway are generally low, ranging from 5% to 10%, because of the fairly high level of regular enforcement. As a result, the relative decline in violation rates for the busway was fairly minor during both the first and second enforcement waves. Violation rates for the AM peak period are plotted in Exhibit 2.32. Violation rates on the San Bernardino Busway failed to return to pre-enforcement levels at any time during the two months following the first wave of special enforcement. However, changing traffic conditions undoubtedly contributed heavily to this apparently long-lasting residual effect. There was less congestion on the freeway during the post-enforcement period, and consequently, less

Exhibit 2.30

LANE VIOLATION RATES BEFORE, DURING, AND AFTER ENFORCEMENT (%)

Period	Marin 101		Alameda 580		San Bernardino Busway		SFO Bay Bridge
	AM	PM	AM	PM	AM	PM	AM
FIRST WAVE (additional officers)	None	(2)	(2)	(2)	(6)	(4)	(2)
Before Enforcement	14.1	29.0	28.5	32.7	7.3	10.5	5.4
During Enforcement	9.9	17.4	25.9	21.3	6.0	7.0	5.1
After Enforcement							
Week 1	9.7	21.2	11.5	19.8	5.4	6.5	4.9*
Week 2	9.9	23.6	25.0*	20.5	4.1	5.4	4.6
Weeks 3 to 4	18.2*	**	24.8	19.0	3.7	4.8	—
Weeks 5 to 6	19.1	25.2*	16.4	21.1	2.6	4.7	—
Weeks 7 to 8	—	33.3	—	25.2	—	—	8.6
SECOND WAVE (additional officers)	None	(0-1)	None	(2)	(6)	None	(2)
Before Enforcement	19.5	22.9	35.1	37.1	7.9	6.9	8.6
During Enforcement	19.5	28.1	23.5	28.8	5.1	5.4	5.8
After Enforcement							
Week 1	**	25.6*	—	—	4.5	3.8	—
Week 2	—	—	31.0*	30.1	6.9*	6.4*	9.6*
Weeks 3 to 4	30.6*	34.8	**	31.2	—	—	8.5
Weeks 5 to 6	28.6	29.0	23.6	34.3*	7.7	5.7	**
Weeks 7 to 8	—	—	—	—	—	—	8.2
THIRD WAVE (additional officers)	—	—	—	—	—	—	(2)
Before Enforcement	—	—	—	—	—	—	8.3
During Enforcement	—	—	—	—	—	—	4.1
After Enforcement							
Week 1	—	—	—	—	—	—	4.7
Week 9	—	—	—	—	—	—	6.3

*Back to pre-enforcement level (within statistical limits)

**Road construction, accident or visibility too poor to view occupancy

Exhibit 2.31

LANE VIOLATION RATE OVER TIME – ALAMEDA 580 (P.M.)

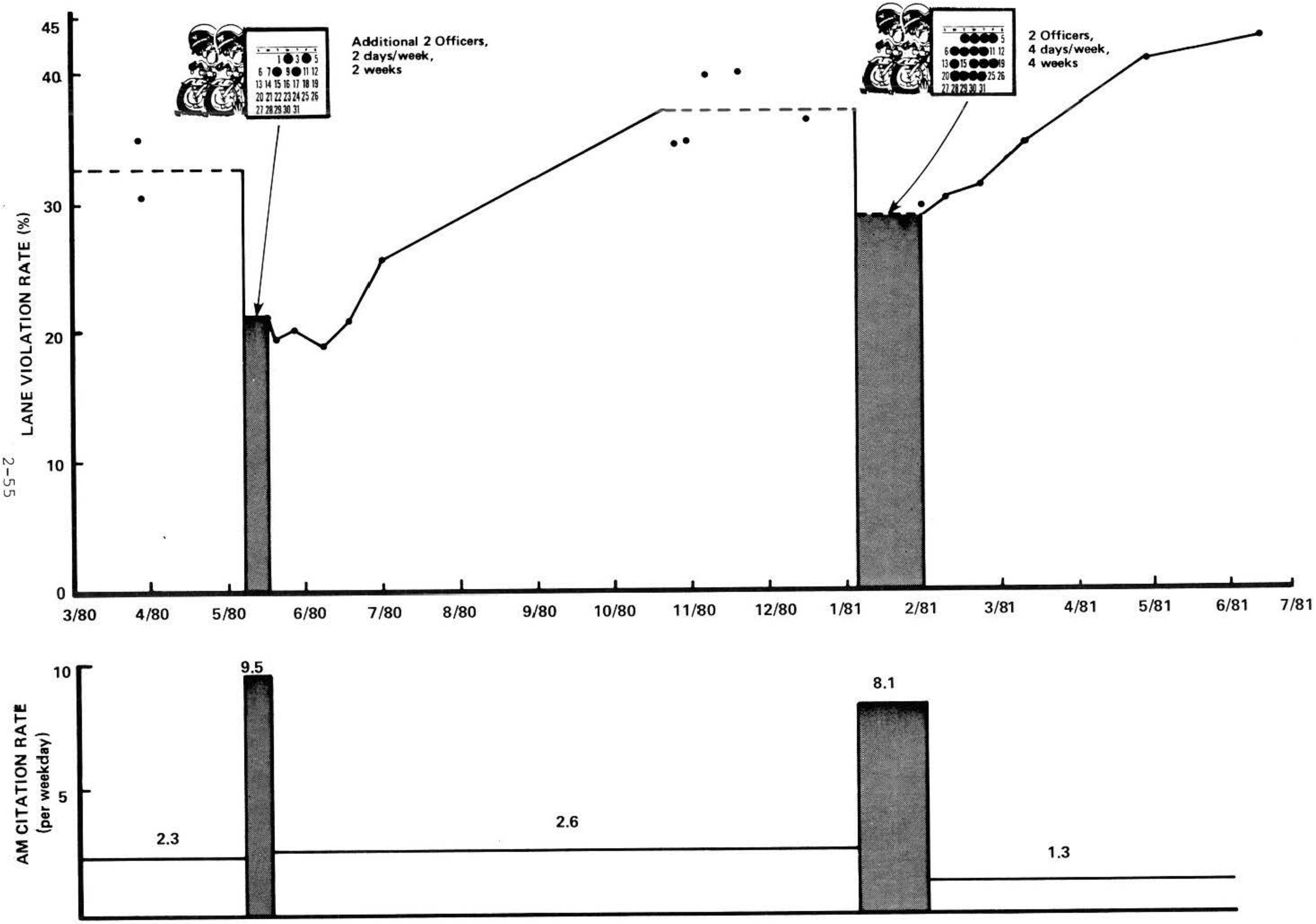
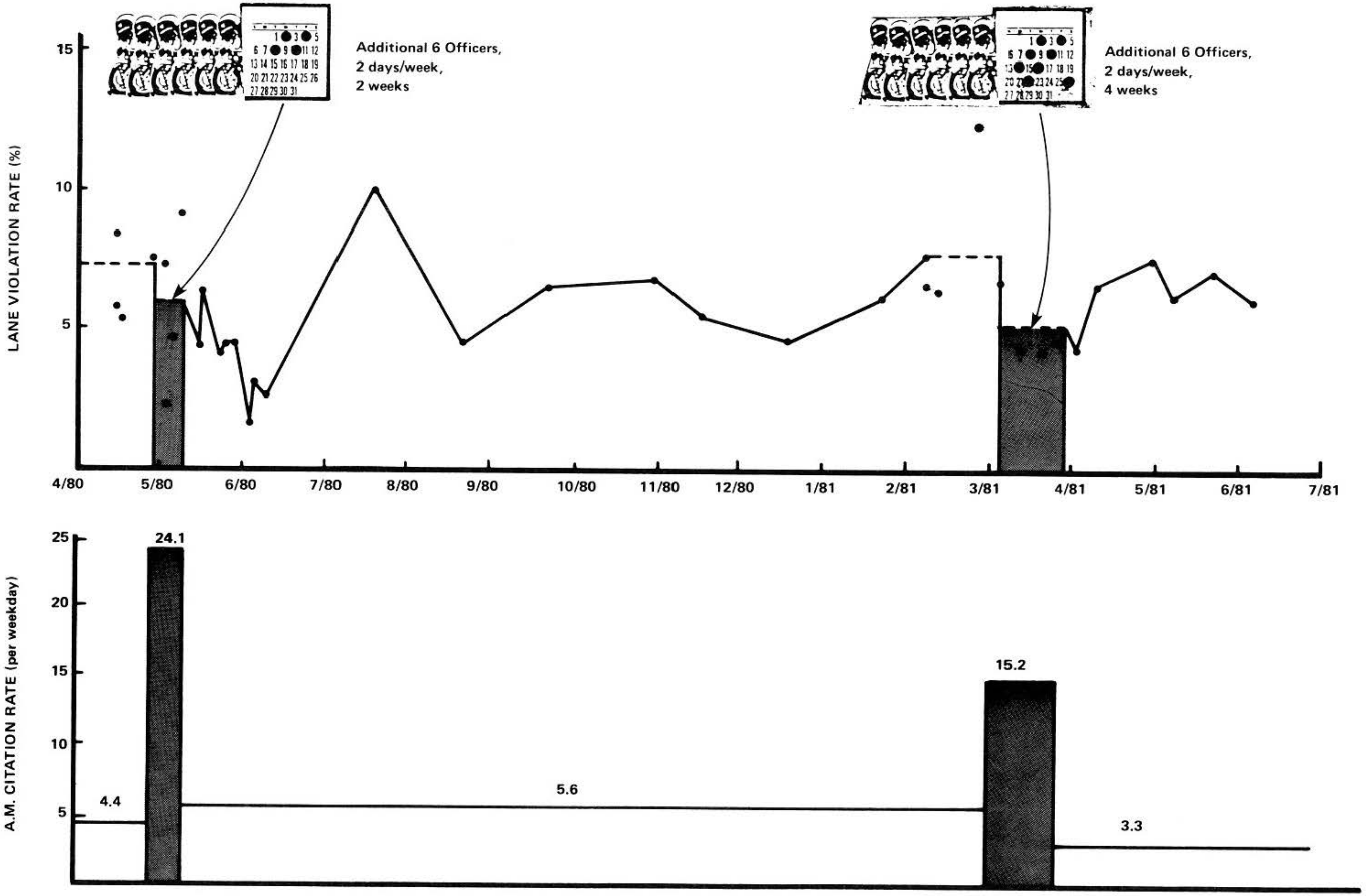


Exhibit 2.32

LANE VIOLATION RATE OVER TIME – SAN BERNARDINO BUSWAY (A.M.)



Additional 6 Officers,
2 days/week,
2 weeks

Additional 6 Officers,
2 days/week,
4 weeks

incentive to violate. This reduction of congestion accompanied the onset of the summer vacation period, and reflected a general spreading of traffic flow over each four-hour peak period, with a consequent reduction in demand during the peak commute hours.

Marin 101. Marin 101, much like the San Bernardino Busway, also has very high levels of HOV lane enforcement. However, the violation rates are much higher on Marin 101, having almost doubled in recent years. Enforcement in Marin has centered almost exclusively on the PM peak period because it has the highest violation rates and congestion is low in the AM period.

The first wave of special enforcement reduced violation rates from 29% to 17% in the PM peak period (see Exhibit 2.33). The violation rates returned to previous levels in about a month. A second wave of enforcement resulted in less clear trends. Enforcement on Marin 101 was stepped up prior to the second wave because of the acquisition of new motorcycles. Up to four motorcycles were assigned specifically to the HOV lane for as many as five days a week. The routine level of enforcement was so high that the period of special enforcement did not increase the number of citations normally written in a month. In fact, the citation rate was somewhat lower than the average and the violation rate actually increased slightly.

Soon after the second wave, routine enforcement was stepped up after new officers were trained for HOV lane enforcement. The citation rate rose to an average of almost 17 tickets a day during the PM peak period and up to 500 tickets in a month have been recorded. Even though enforcement was so vigorous, the violation rate remained between 20% and 30%.

Volume counts and speed checks show that traffic conditions have varied little over the years so the incentive to violate has not changed. One possible explanation for the high violation rates lies in the difficult and anonymous nature of enforcement activities. CHP officers must escort violators across three lanes of traffic to the shoulder so many freeway users are unaware of what the violator is being cited for. (A survey of drivers revealed that Marin 101 users had the lowest awareness among the three mainline projects of HOV lane enforcement despite Marin's actual high level of enforcement.) At the same time, since the CHP officers spend much of their time on the shoulder, violators are free to pass with little chance of being caught. On both the San Bernardino Busway and Alameda 580, a violator passing an officer in the act of issuing a ticket is liable to be waved over himself. This cannot happen on Marin 101, since tickets are issued far from the lane itself. Since there are less than 200 violators during the two-hour peak period, and 500 tickets are issued each month, it appears that the same individuals are not violating each day.[5] In fact,

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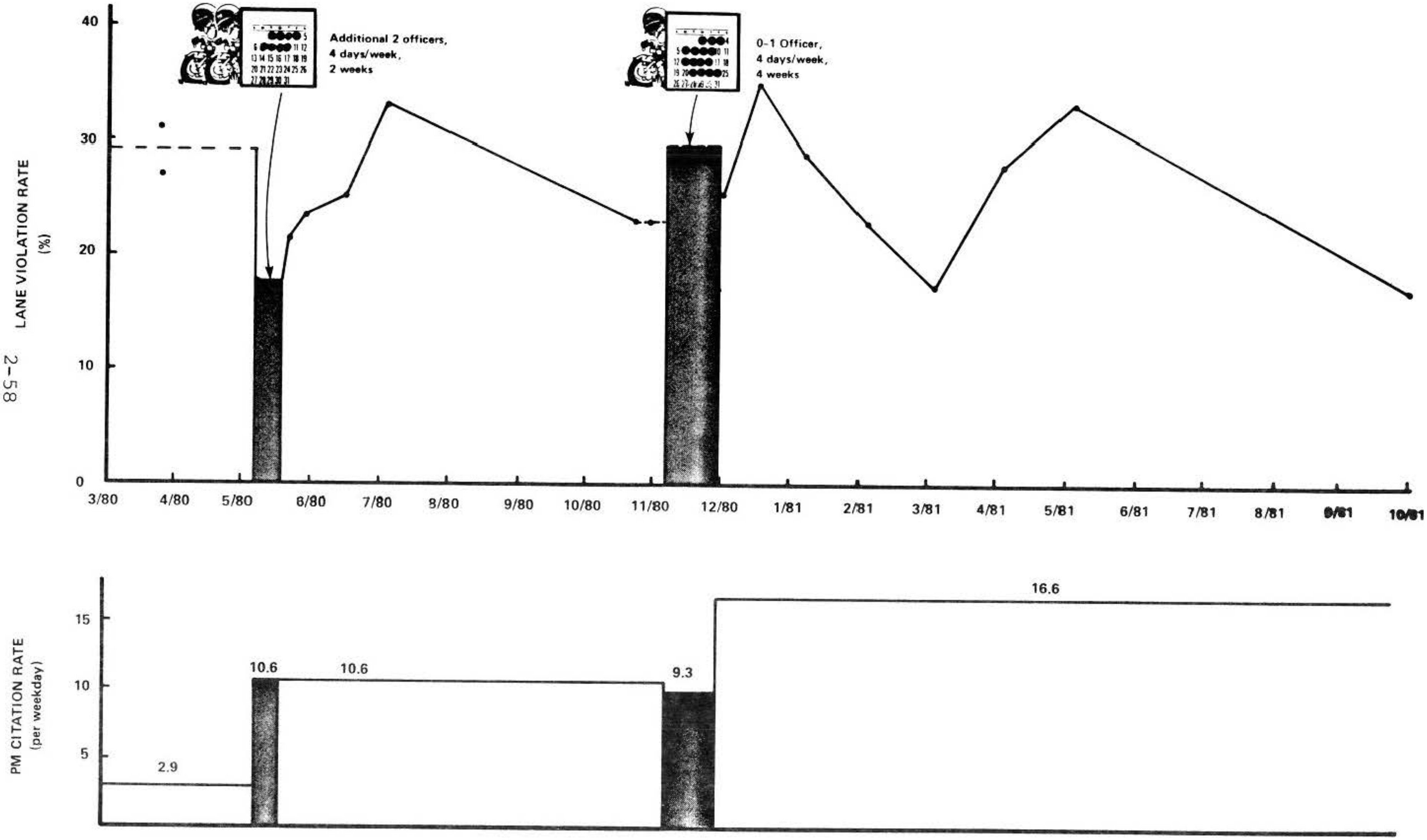
[5] A license plate sample taken over a three day period suggested that under six percent of all violations were caused by repeat violators (see Section 5.4.3).

Exhibit 2.33
LANE VIOLATION RATE OVER TIME – MARIN 101 (P.M.)



since the pool of violators has yet to dry up, it is as if "everyone wanted to try it once." However, the saturation point may have been reached. In late September 1981, the violation rate had dropped to 17% (observed at a slightly different location). Future counts will determine whether the current high level of enforcement can maintain the violation rate below 20%.

During the first enforcement wave on Marin 101, it was noticed that the morning violation rate dropped even though special enforcement only took place during the evening peak. The violation rate presumably drops in the morning because the drivers are more cautious after they see the evening enforcement activity. In order to test this hypothesis, enforcement during the second wave was limited to only one peak period on all three mainline lanes: PM enforcement for Alameda 580 and Marin 101, and AM enforcement for the San Bernardino Busway. In each case, the violation rate for the non-enforced period dropped significantly during the second wave. The reduction in violation rates in the non-enforced peak period was smaller than the enforced period's reduction for Marin 101 and the San Bernardino Busway, but the drop was slightly more for Alameda 580. Violation rates uniformly returned to pre-enforcement levels during the non-enforcemed periods. The results imply that it may not be necessary to have a full day of special enforcement in order to discourage violations.

<u>San Francisco/Oakland Bay Bridge</u>. The San Francisco/Oakland Bay Bridge has a fairly low lane violation rate of 5 to 10%. The low violation rate is partly due to the unique characteristics of the Bay Bridge carpool lanes:

- Violators are highly visible and must pass long lines of non-carpoolers adjacent to the carpool lane. This may be a psychological deterrent.

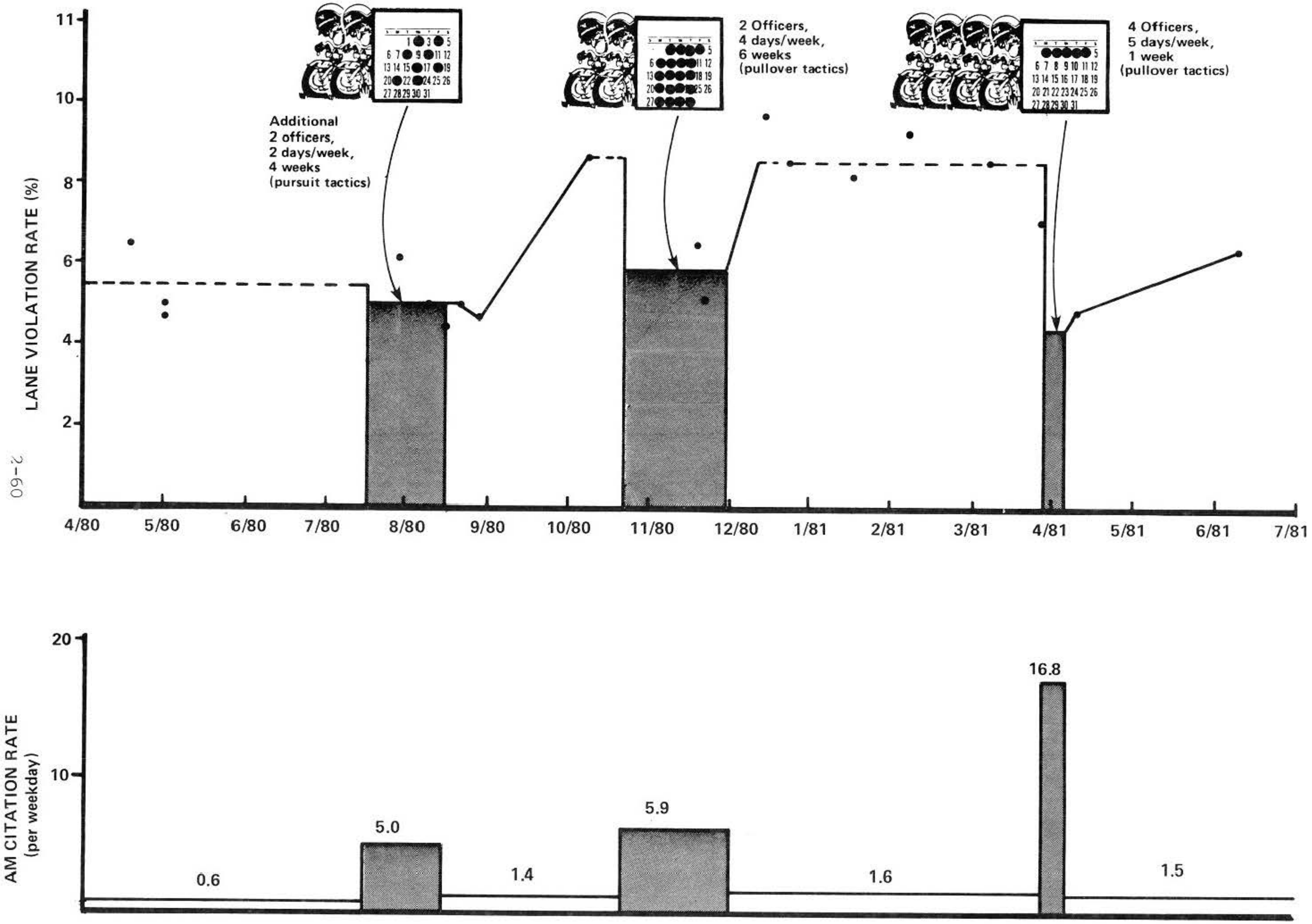
- A violator must decide early to violate in order to merge into the carpool lane. Pulling out of the lines at the toll booths into the carpool lane is hazardous since the carpoolers speed through the toll booth without stopping.

- Similarly, it is difficult to stop and merge into the general lanes if enforcement officers are spotted ahead.

- An individual toll booth processes approximately one vehicle every 6.7 seconds. At this rate, vehicles in the waiting queue are constantly moving, presumably relieving the annoyance felt by potential violators. A similar phenomenon was observed in the case of ramp bypass lanes (see Section 3.1.1). For rapid metering cycles of 4 to 6.5 seconds, violation rates were lower than for slower cycles offering comparable delays. Given the same delay, drivers appeared to be more willing to stay in a long queue which was moving rapidly than in a short queue which was moving slowly.

Exhibit 2.34

LANE VIOLATION RATE OVER TIME – SAN FRANCISCO/OAKLAND BAY BRIDGE (A.M.)



Additional
2 officers,
2 days/week,
4 weeks
(pursuit tactics)

2 Officers,
4 days/week,
6 weeks
(pullover tactics)

4 Officers,
5 days/week,
1 week
(pullover tactics)

Exhibit 2.34 traces the impact of three waves of enforcement on violations on the San Francisco/Oakland Bay Bridge. First wave enforcement activities had little impact on violation rates. The reduction was minor partly because violation rates were so low to begin with and also because the technique of pursue and pull over was used to apprehend violators. Second-wave enforcement techniques were changed to the more visible technique of waving over violators soon after they leave the tool booth. More tickets can be written using this technique. A third wave of enforcement was carried out a few months after the violation rates had stabilized at 8%. Enforcement was very intense: 4 officers enforced the carpool toll lanes each weekday for one week. Enforcement reduced the violation rate to 4.1%. The SFOBB results were consistent with bypass ramp results in that there appears to be a virtual lower limit to the violation rate which no practical level of enforcement can crack. In the case of the SFOBB carpool lanes the lower limit to the lane violation rate appears to be about 4%.

San Francisco/Oakland Bay Bridge violation rates were unusually high (8.6%) just before the second wave, presumably because of the minimal enforcement activity after the first wave of special enforcement. Heavy enforcement activities in late October 1980 and throughout November reduced the violation rates to historical levels but not any lower. The violation rates quickly returned (within two weeks) to pre-enforcement levels after special enforcement.

2.2.4 Impact on Freeway Flow

To determine the impact of mainline HOV lane enforcement on traffic in adjacent freeway lanes, CALTRANS made a series of tachometer runs on each of three mainline HOV projects: Marin 101, Alameda 580, and the San Bernardino Busway. These floating car runs were made in the non-HOV lanes (the HOV lanes were essentially freeflow at all times) before and during special enforcement periods. The table below summarizes the effects on average speed in adjacent lanes over the length of each HOV projects.

AVERAGE MAINLINE SPEEDS IN ADJACENT LANES
BEFORE AND DURING ENFORCEMENT (MPH)

	MARIN 101	ALAMEDA 580		SAN BERNARDINO BUSWAY	
PERIOD	PM	AM	PM	AM	PM
FIRST WAVE					
Before Special Enforcement	51	59	55	40	41
During Special Enforcement	52	50	53	33	39
SECOND WAVE					
Before Special Enforcement	53	**	53	36	**
During Special Enforcement	*	**	56	35	**

*Tachometer malfunctioned.
**No special enforcement during this peak period.

Enforcement activities had little effect on the free flow of traffic on Marin 101 and Alameda 580. Free-flowing traffic in adjacent lanes on Marin 101 was essentially unaffected by enforcement actions taken against HOV lane violators, even though CHP officers pursue violators and escort them to the side of the road before issuing tickets. Surveys showed that most drivers using Marin 101 were unaware that this enforcement activity was directed toward HOV lane violators. Alameda 580, however, experienced slight reductions in speed during the first wave. These effects were fairly minimal when viewed in terms of travel time; travel delays of slightly over one minute occurred on special enforcement days. During the second wave, speeds actually increased slightly during special enforcement.

Several roadside observers reported that special enforcement activities on the San Bernardino Busway appeared to generate significant amounts of disruption and congestion as gawkers slowed to watch and traffic was interrupted to apprehend violators and return them to the normal flow of traffic. Speed data assembled through a series of tachometer runs made over the length of the project partially confirmed these observations. While it is true that freeway speeds during the evening peaks were often low during periods of enforcement, they were nearly as low on days when no special enforcement was undertaken. The above table shows that the average speed attained during the evening peak by a sequence of autos leaving Los Angeles at 15-minute intervals and following general traffic lanes to the end of the San Bernardino Busway was 41 miles per hour in the base period. This speed dropped slightly, to 39 miles per hour, on days when special enforcement activities were scheduled. This drop is equivalent to an increase of 1.3 minutes in travel time for a commuter traveling the length of the project.

The travel delays accompanying special enforcement were greater during the morning commute period than during the evening peak. During the morning peak, speeds averaged 40 miles per hour prior to enforcement, and dropped to 33 miles per hour during enforcement, reflecting an increase of 4.2 minutes of travel time over the 13.3 mile length of the project.

The San Bernardino Busway was singled out for special study during the second wave of enforcement because of the observed congestion on the freeway. The policies of minimal stacking, minimal bunching of officers in one area, release of violators into busway and limited pursuit across mainline lanes (described in Section 2.2.2) were used in order to minimize traffic slowdowns. The effects of enforcement are apparent in the congested sections of the busway. In these sections of the freeway the traffic is nearer to stop-and-go conditions and so enforcement activities would have a larger effect on speeds. Since the number of special enforcement units remained the same for the first and second wave, the effect of enforcement on traffic speeds for each wave can be compared. The speeds for the congested segments are summarized below.

AVERAGE SAN BERNARDINO SPEEDS (MPH)
CONGESTED SECTIONS OF FREEWAY

	AM		PM	
	(Busway on-ramp to Warwick)		(Herbert Ave. to Atlanta Blvd.)	
Period	First Wave	Second Wave	First Wave	Second Wave
Before Special Enforcement	28	33	29	38*
During Special Enforcement	21	28	24	41*

*No special enforcement during PM.

The second wave of enforcement had less of an impact than the first wave on traffic flow in the congested section of the freeway. During the PM, there were no statistically significant differences in speeds before and after the first wave of special enforcement. Thus, special enforcement activities appear to have had a small effect on the less congested PM peak period. During the AM peak period, the speeds did not differ significantly before enforcement began. However, speeds during enforcement did not drop as much during the second wave as during the first wave. It is also important to note that the speeds recorded in the AM are within the critical range of 20 to 30 MPH where slight changes in speeds can cause stop-and-go traffic. The low speeds during the AM peak probably accentuate the effects of enforcement and make enforcement-caused slowdowns highly visible.

In summary, the second wave of special enforcement on the San Bernardino Busway had a minimal effect on traffic speeds for the entire length of the freeway but resulted in a slight drop in speeds for the severely congested segments of the freeway. The adoption of a policy to avoid stacking, avoid bunching, release violators into the busway and limit pursuit appeared to have minimized adverse effects on traffic flow without blunting the CHP's ability to reduce violation rates.

2.3 SUMMARY

Experimentation with different enforcement strategies, tactics, schedules, and levels has produced several insights into the effect of enforcement on HOV project violation rates. Subsequent chapters explore the engineering implications of these insights and use the experimental results to formulate enforcement programs for ramp meter bypass lanes and mainline HOV lanes. This subsection summarizes the key findings regarding the relationships between enforcement and violations described in detail earlier in this chapter.

2.3.1 Ramp Meter Bypass Lanes

Historical Enforcement Lanes. In the past, the CHP has applied a policy of relatively low-priority, routine enforcement to bypass lanes, using available personnel to enforce the lane restrictions in addition to regular patrol duties. As the number of bypass lanes in Los Angeles approaches 150, however, the supply of bypass lanes in some CHP command areas has actually outnumbered the supply of officers available for all patrol duties during the peak traffic periods. As a result, a ramp-by-ramp survey of seven command areas in Los Angeles and two in San Diego showed that the average number of occupancy citations issued per bypass lane was slightly over one per week at the start of this study.

Under this enforcement policy, violations increased annually on most ramp meter bypass lanes in the Los Angeles area, and bypass lanes that had been operational for several years had significantly higher ramp violation rates than newly-opened lanes. The relative number of vehicles using ramp bypass lanes illegally ranged from a low of 2.4% to over 38% of all vehicles on the ramp, and averaged 12.5% on a sampling of 36 Los Angeles ramps. HOV ramp violation rates were found to be considerably lower (averaging 3.0% on a sampling of seven HOV bypass lanes) in San Diego, where the peak traffic periods are shorter, meters are traffic-responsive, and the HOV lanes themselves are meter-controlled.

Special Enforcement Activities. Four waves of special ramp enforcement activities were scheduled in Los Angeles and San Diego between June 1980 and August 1981. During each enforcement wave, officers were assigned to particular ramps for a specified number of days each week for periods of one week, four weeks, or twelve weeks. These special assignments were applied randomly and interspersed with periods of routine enforcement lasting at least nine weeks.

The first wave of enforcement was easily the most effective in reducing violation rates. During the first wave, special enforcement activities proved successful in reducing ramp violations on almost every ramp where they were tried. Even the lowest levels of special enforcement (one officer, one day per week, for four weeks) had a significant, measurable impact in lowering violation rates. Moreover, violation rates tended to remain low for as long as four to eight weeks following the cessation of special enforcement activities.

Although the relative effectiveness and residual impact of special enforcement diminished somewhat following the first wave, heavier enforcement levels (enforcement two or more times a week) still caused violation rates to decline, and the lower enforcement levels (enforcement once a week or less) generally managed at least to keep rates from rising and maintain earlier reductions. At the close of the fourth wave, violation rates on the ramps subjected to special enforcement stood at 6.5%, a 45.4% reduction below the 11.9% rate characterizing those ramps at the start of the study. The median span of time before violation rates approached pre-enforcement levels was two weeks following the later waves of enforcement, as compared with eight weeks following the first wave.

Special Enforcement Tactics. The most popular and effective tactic for enforcing ramp bypass lanes required that officers park their vehicles beyond the meter, and assume a stationary position to wave violators over to a safe refuge area where a citation could be issued. Officers who were able to stand out of the view of potential violators issued more citations per day than officers who assumed more visible positions. Some officers appreciated the extra margin of safety afforded by in-view enforcement, however, and these officers tended to be no less effective in reducing violations. Violations were somewhat slower in returning to pre-enforcement levels when enforced from less visible positions.

Enforcement tactics involving vehicle pursuit were much less efficient than stationary enforcement in generating citations, reducing violations, and providing a cautionary example to other ramp users.

Because violations of the ramp meter itself (i.e., by running the red light) occur much less frequently than violations of HOV lane restriction and pose less of a threat to freeway performance, officers assigned to special ramp enforcement duties should be instructed to concentrate on enforcing occupancy violations.

Routine Enforcement. In the absence of special enforcement, routine enforcement proved to be an ineffective means of controlling ramp violation rates. Attempts to increase routine enforcement levels by requiring officers to spend ten minutes of each day on ramp enforcement also proved ineffective. Such efforts produced a low level of citations, were difficult to direct and control, were unpopular with some officers, and tended to encourage one-shot enforcement tactics involving pursuit rather than a sustained effort from a stationary position.

Routine enforcement can be effective if applied in conjunction with special enforcement in a selective enforcement program. Violation rates rose relatively slowly during the periods of routine enforcement separating special enforcement sessions on sample ramps. As drivers became aware of special enforcement activities on sample ramps, moreover, violation rates dropped on other routinely enforced ramps. On six Los Angeles ramps subjected only to routine enforcement, violation rates dropped 20% between the first and fourth waves of special enforcement.

Effect of Violation Levels. Special enforcement was most effective on ramps where violation rates were medium or high to begin with. On ramps where violation rates were already low (i.e., under 6.5%) special enforcement had less impact in reducing occupancy violations further, and violation rates returned to pre-enforcement conditions much faster. This suggests that there is a practical limit on the reductions that can be brought about by enforcement, and consequently that special enforcement efforts should not be expended in an attempt to make tolerably low violation rates lower still.

The need to relate enforcement levels to existing violation rates underscores the need for close, continuing cooperation between the enforcement agency and the agency responsible for maintaining, operating, and monitoring ramp meter bypass lanes.

Duration of Special Assignments. Twelve-week periods of enforcement were not found to be significantly more effective than four-week periods either in reducing violations further or in generating longer residual impacts. The diminished effectiveness of longer periods of enforcement, coupled with the lessened impact of later waves of special enforcement and the difficulty of driving ramp violation rates below 4 or 5%, suggests that enforcement impacts are subject to a law of diminishing returns.

Number of Officers. Assigning two officers to a single ramp was almost -- but not quite -- as effective as assigning a single officer for twice as many days. On some heavily violated ramps, the officers themselves prefered working in pairs so that fewer violators went unticketed and help was close at hand in the event that apprehended drivers became unruly while waiting to be ticketed.

Start-Up Strategies. Start-up enforcement strategies were tested by selecting matched pairs of newly-opened ramp bypass lanes similar in geometric configuration and enforcement visibility, and initiating special enforcement activities on one ramp of each pair, while restricting the other ramp to low-priority routine enforcement. Special enforcement activities lasted for four weeks and were repeated quarterly on certain ramps. After one year of ramp operation, ramps receiving special enforcement during the opening weeks had significantly lower violation rates than their opposite numbers. The composite ramp violation rate on ramps receiving special enforcement was 7.3%, as compared with a rate of 14.0% on control ramps exposed only to routine enforcement.

Special enforcement activities should be initiated immediately after a ramp is opened and be continued for at least two days a week during the first month of operations. If an initial grace period is desired, it should last no more than a week and should generally not be publicly announced. Officer presence should be maintained throughout that week to issue warnings, answer questions, and instill a degree of respect for the HOV restrictions.

Bail Schedules. Bail schedules for HOV lane occupancy violations vary from $21.00 to $52.00 in the CHP's Southern and Golden Gate Divisions, and are set at a low of $13.50 per offense in the San Diego area. There was little evidence that higher fines led to significantly lower violation rates, but a fine of $13.50 does not begin to cover the publicly borne costs of apprehending violators and processing citations (see Section 6.1.3).

Prior to project opening, court officials should be briefed regarding the goals, traffic restrictions, enforcement programs and legal basis associated with projects involving ramp meters and bypass lanes.

Impacts on Traffic Flow. As special enforcement encouraged more single-occupant autos to join the metered queue rather than use the HOV lanes illegally, queue lengths grew, and the average delay encountered by drivers entering Los Angeles freeways rose from 45 seconds to 54 seconds. In addition, special ramp enforcement actions were found to reduce speeds on adjacent freeways by between 20% and 30% in the vicinity of the ticketing activity.

Whenever possible, officers should enforce ramps out of the view of mainline traffic to avoid disrupting flow on the freeway itself.

2.3.2 Mainline HOV Lanes

Historical Enforcement Levels. Past citation rates on mainline HOV lanes have been considerably higher than those for bypass ramps, and range from a low of four tickets per weekday on Alameda 580 to 14 tickets per weekday on the San Bernardino Busway. On Alameda 580, the CHP has historically relied on routine enforcement to control violation rates, while motorcycle officers have been assigned to special enforcement duties during the evening peak on Marin 101. On the San Bernardino Busway, a combination of routine and special enforcement was used in the past, with special enforcement units assigned intermittantly to lane enforcement.

Under these enforcement policies, violation rates had risen only slightly on the San Bernardino Busway since the projects began carpool operation. The number of vehicles using the busway illegally during the pre-enforcement phase of this study averaged 8.8% of all vehicles in the HOV lane. Occupancy violations on the shoulder-separated right-of-way of the Busway averaged 7.3% of all vehicles in the lane during the morning peak and 10.5% of all vehicles in the afternoon. These violation rates were lower still (estimated at 3% to 4%) on the portion of the Busway where a physical barrier makes lane-switching impossible. Lane violation rates on the controversial Alameda 580 diamond lanes had doubled over the life of the project and stood at 30.5% prior to the initiation of special enforcement. The corresponding violation rate on Marin 101 averaged 21.5%, up from an average of 15% when the lanes were opened to carpool use.

Special Enforcement Activities. Two waves of special enforcement activities were scheduled on each mainline HOV lane in California between May 1980 and June 1981. During the first wave from two to four additional officers were assigned to each project for a two-week period in May 1980. During the second wave, a similar number of officers were assigned to enforce throughout either the morning or evening commute hours (but not both) for a period of four weeks. The first wave of special enforcement reduced violation rates significantly on all three projects. Violation rates on both Alameda 580 and the San Bernardino Busway remained lower than pre-enforcement levels for at least eight weeks, when the summer vacation period began. Marin 101 experienced large reductions during both the morning and evening peaks, even though special enforcement activities were only scheduled during the evening commute hours. The percent reduction, however, was smaller in the morning, and conditions returned to normal faster.

On both Alameda 580 and the San Bernardino Busway, the second enforcement wave reduced violation rates during both commuting periods, even though special enforcement was limited to the evening peak in Alameda County and the morning peak on the San Bernardino Busway. Violations returned to pre-enforcement levels within two to six weeks after special enforcement ceased. For the morning peak in Alameda county and the evening peak on the Busway, however, these violation levels were significantly lower than those measured a year earlier at the start of the study. In Marin County, violation rates fluctuated wildly after the second enforcement wave, and reached levels considerably higher than those measured prior to enforcement. During the morning peak period, which had received only relatively low levels of routine enforcement throughout the study, violation rates on Marin 101 had doubled by the close of the study. There was no significant increase during the evening peak, which received higher levels of routine enforcement than any other TSM project.

The results of the study suggest that a program of selective enforcement, with a month of special enforcement undertaken at relatively infrequent intervals, is capable of controlling violation rates on mainline HOV lanes, so long as routine enforcement is not neglected during the intervening periods. Routine enforcement levels averaged two citations per peak period on Alameda 580, four per period on the San Bernardino Busway, and nearly eleven per period during the evening peak on Marin 101. It is cost-effective to concentrate special enforcement during any month in a single peak period, so long as neither peak is neglected in the long run. Enforcement should be concentrated most often in that direction which least interferes with traffic flow.

Impact of Enforcement on Traffic Flow. When mainline lanes are congested, special enforcement activities can cause further traffic disruption as gawkers slow to observe ticketing activities. To minimize the effect of these activities on mainline flow, special enforcement officers should avoid bunching together, limit stacking so that no more than one car is waiting to be ticketed at any time (in addition to the vehicle being cited), release cited motorists into the busway rather than into the mainline lanes, and avoid pursuing violators across several lanes of traffic.

2.3.3 Special Bridge Lanes

Most of the comments regarding the enforcement of ramp meter bypass lanes apply equally well to the enforcement of special toll plaza lanes. On the San Francisco/Oakland Bay Bridge, the practice of waving violators over into a coned-off refuge area proved more effective both in producing citations and in lowering violation rates than the practice of using motorcycles to pursue violators.

3. DESIGN IMPLICATIONS

This chapter explores those questions of TSM project design which have a bearing on enforcement and violation rates. Quantitative evidence regarding violator behavior is reviewed in the light of design issues affecting ramp meter bypass lanes, mainline HOV lanes, and exclusive toll plaza lanes on bridges. The effect of violations on freeway performance is addressed, and the results of special studies regarding distinctive striping and lane separation are summarized.

3.1 RAMP METER BYPASS LANES

3.1.1 Impact of Design on Violations

Metering Rates, Queue Lengths, and Driver Delays. Driver delays on metered ramps are a function of both queue lengths and the metering rate. Since the metering rate is selected by the design engineer, an important element of driver delay, and consequently, an important source of temptation to the potential violator, is within the control of the system designer. One of the questions of interest in this study is:

> "Do occupancy violations occur more frequently when delays in the metered lane are longer?"

In an attempt to answer this question quantitatively, ramp violation rates observed at five-minute intervals on 39 Los Angeles ramps were plotted against the delays existing during the corresponding interval.[1] Exhibit 3.1 suggests that there is little correlation between ramp violation rates and the delays encountered in the metered lane. Although violation rates increase slightly with delay, a large

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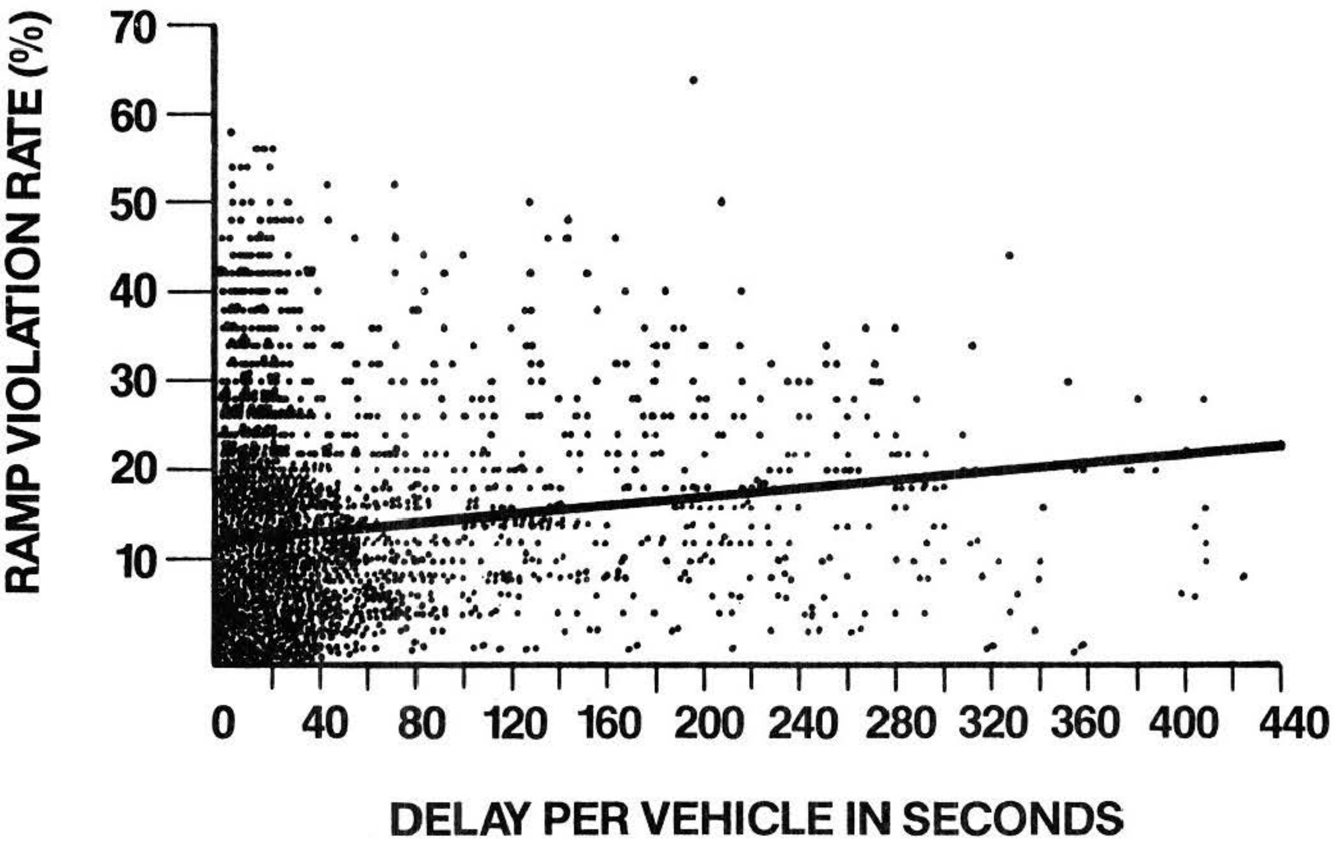
[1] Queue lengths were recorded once each minute and averaged to obtain a measure for the five-minute interval. Because queue lengths can vary markedly within five-minutes, it was feared that the five-minute average might not accurately reflect the delay encountered by each violator recorded during the interval. To test this possibility, time-lapse photography was used on eight sample ramps to record the actual queuing situation faced by each violator. A frame-by-frame analysis of the time lapse photography indicated that the mean queue length encountered by violators did not differ significantly from the queue length sampled every minute, and confirmed the finding that the duration of driver delay has little impact on ramp violation rates. Details of this analysis may be found in Interim Report No. 1. (Reference 4).

Exhibit 3.1

RAMP VIOLATION RATE VS DELAY

(39 LOS ANGELES RAMPS)



proportion of the observed violations occurred when delays were under 20 seconds. Short delays were not uncommon on the ramps, as the majority (52%) of the intervals observed exhibited delays of less than 20 seconds. A multiple regression analysis confirms the conclusion that no linear relationship exists between delays and ramp violation rates. Delay alone accounts for only 2.3% of the variance observed in the ramp violation rates, while the combination of queue length, metering rate, and delay account for only 13.5% of the observed variability. From thirty-nine sample Los Angeles ramps and seven San Diego ramps, there was not a single ramp on which violation rates were found to be highly correlated with ramp delays.

A somewhat simpler view of the delay/violation relationship appears in Exhibit 3.2, which classifies observations in different delay intervals and displays the average ramp violation rate computed for each interval. Although the average ramp violation rate increases slightly as delays increase, rising to 19% for delays of 120 to 140 seconds, the ramp violation rate recorded for the lowest delay category (0-20 seconds) was a formidable 12%.

Exhibit 3.3 plots the mean ramp violation rate for successive intervals of metering rates (total red + green cycle time for the ramp meter). As in the case of total delays, average violation rates increased as the meter cycle time increased. Further analysis shows, moreover, that when delays are held constant, there is a sight positive correlation between ramp violation rates and metering rates (r = .36). This suggests that people's perceptions of delay stem not so much from the queue length as from the metering rate. Given the same delay, drivers appear to be more willing to stay in a long queue which is moving relatively fast (i.e., has a short meter cycle) than in a short queue which is moving very slowly because of a long red phase in the meter cycle.

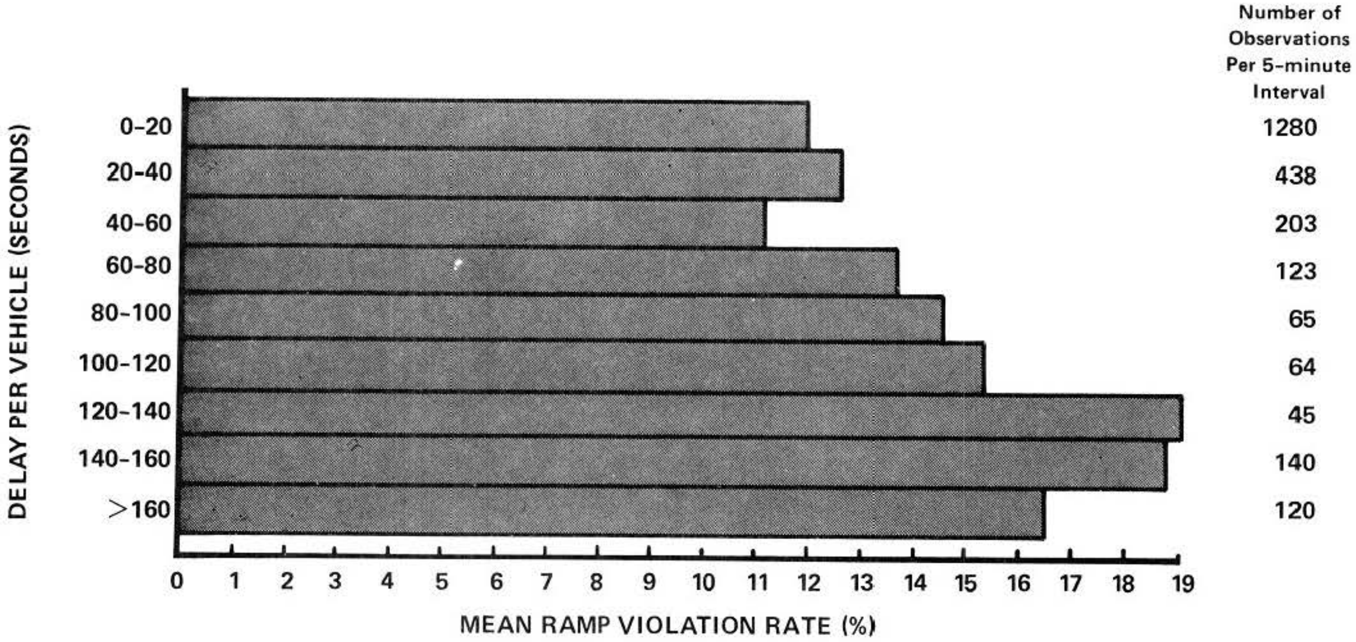
There are several possible explanations for the relatively heavy violation rates observed when queue lengths are short or non-existent. The most likely explanation is that <u>any</u> delay seems longer than it actually is. Surveys show that drivers wildly overestimate the time to be saved by using the ramp bypass lane, especially when the actual time savings is relatively small (see Chapter 5).

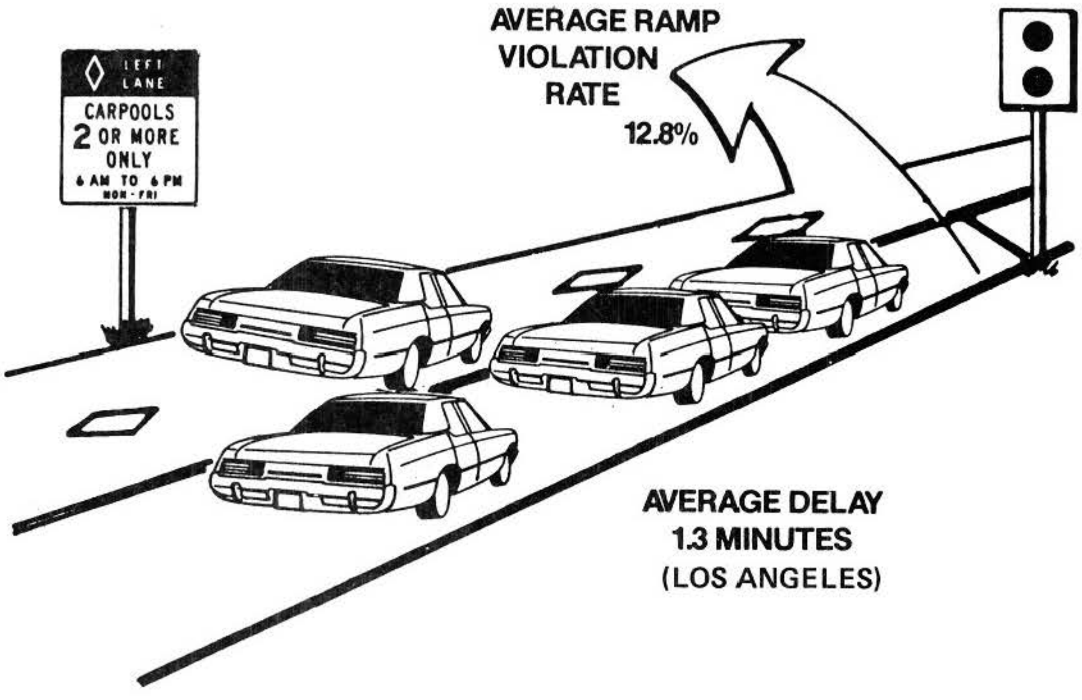
Some drivers apparently violate the HOV lane simply to avoid stopping at the meter. Roadside observations and time-lapse photography show that some violations occur even when the non-HOV lane has no cars at all. These drivers may perceive running a red light to be a more serious violation or potentially more hazardous to their health than using an HOV lane illegally. Moreover, when there are few cars waiting in the metered lane, drivers may perceive their risk of apprehension to be smaller since the actual time spent in the HOV lane is shorter and they are close enough to the meter to know whether a CHP officer is stationed beyond the queue. On ramps classified as queue-dependent (i.e., on those ramps where a driver needs to travel some distance along the ramp before he can tell whether an enforcing officer is present), average ramp violation rates are higher when delays are shorter than

Exhibit 3.2

MEAN RAMP VIOLATION RATE VS. DELAY PER VEHICLE ON 39 RAMP BYPASS LANES IN LOS ANGELES

(Pre-Enforcement Data)



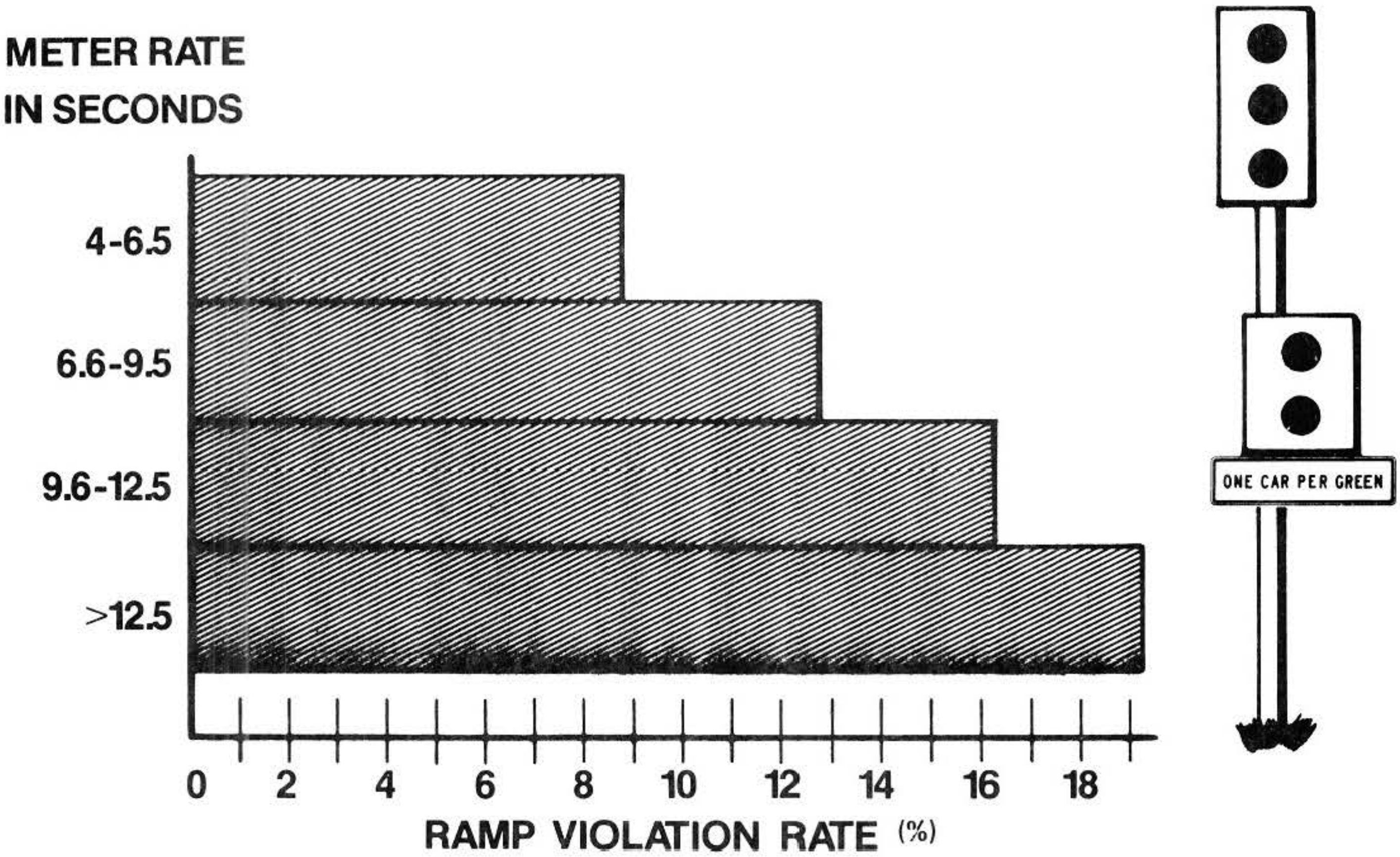


AVERAGE RAMP VIOLATION RATE 12.8%

AVERAGE DELAY 1.3 MINUTES (LOS ANGELES)

Exhibit 3.3

IMPACT OF METER RATE ON RAMP VIOLATIONS



when queue lengths are longer. Finally, drivers may feel less peer pressure to conform when the non-HOV queue length is short than when the queue is long.

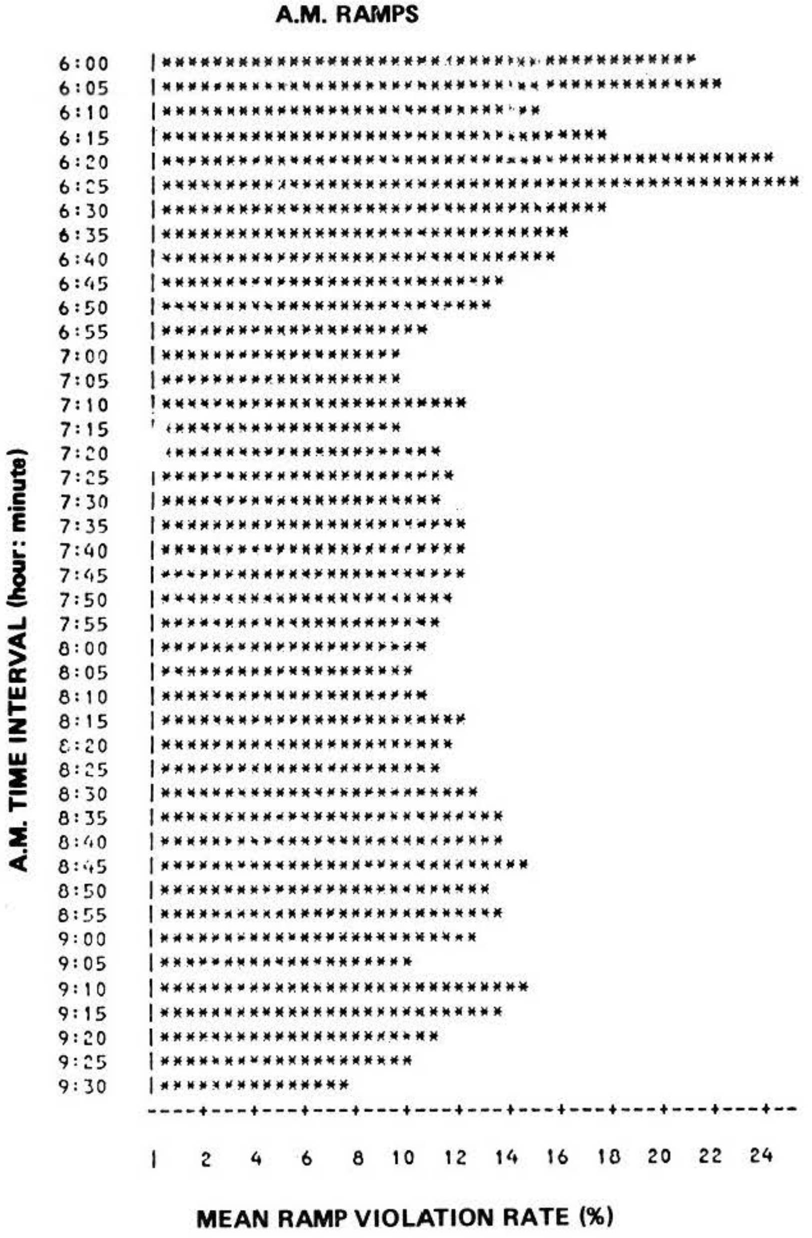
Time of Day. Exhibit 3.4 graphs the mean violation rate for a sampling of 39 Los Angeles ramps as a function of time of day for both AM and PM peak periods. The highest ramp violation rate in the morning (25%) was observed between 6:20 a.m. and 6:25 a.m. while the highest ramp violation rate in the afternoon (26.9%) was recorded between 6:15 p.m. and 6:25 p.m. The mean ramp violation rate for the two peak metering periods was 12.3% in the morning and 13.3% in the afternoon.

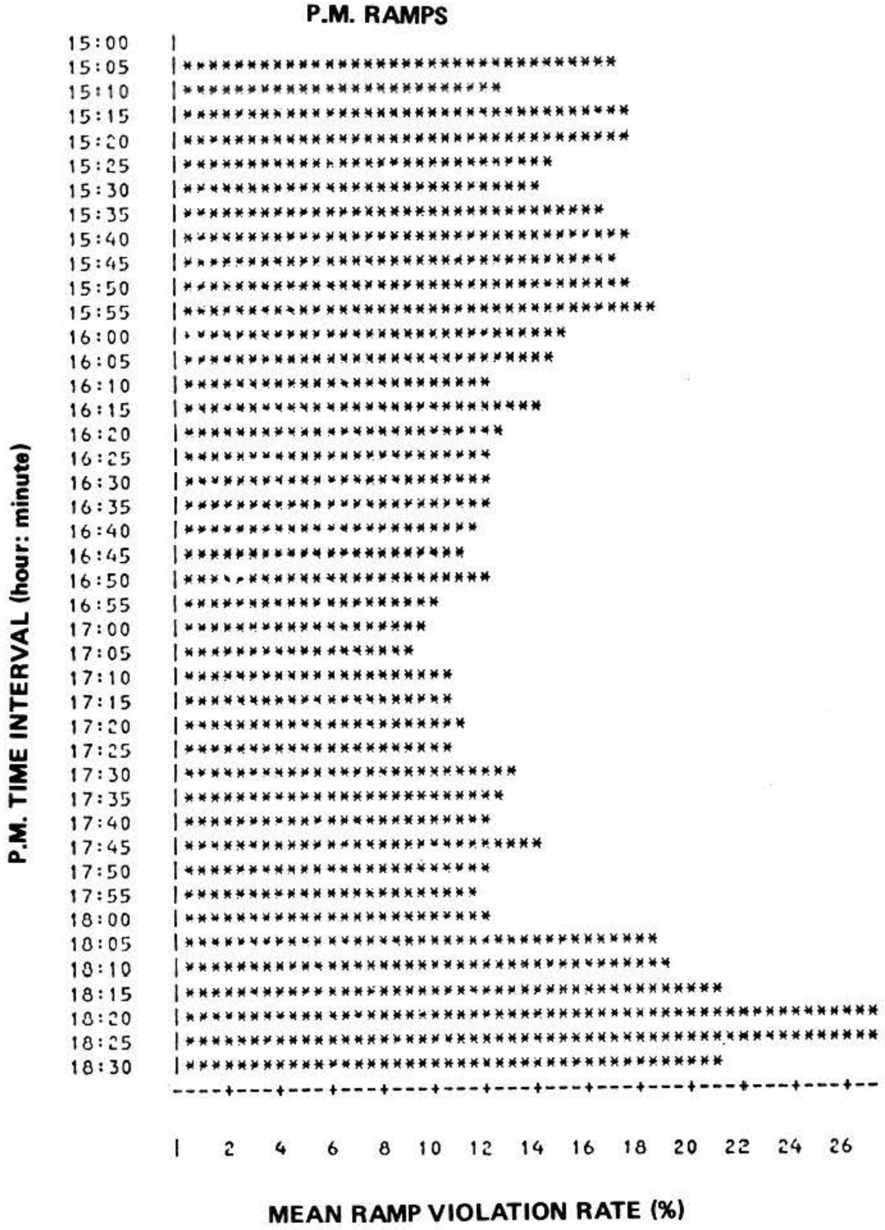
These results indicate that violation rates on Los Angeles bypass lanes are somewhat higher at the beginning and ending of the metering periods. Moreover, the violation rates are highest at the beginning of the morning period and at the end of the evening period, when darkness can make the lanes difficult to enforce and difficult to observe. Enforcement efforts have traditionally been relatively light during the early morning hours, as a result of darkness during the winter months and CHP shift changes, which occur just as the meters begin to operate. Another factor which may contribute to heavier violation rates at the fringes of the meter operating period is the normal variation in the travel time of the individual commuter. Those who normally travel during the early (or late) hours when the meters are not operating may tend to violate more when they encounter the meter in operation (especially if they are already late in getting to work).

The tendency for violations to concentrate at the fringes of the operating period is not nearly so great with metered bypass lanes as with barrier-free HOV lanes on mainline freeways. Different HOV project designs can affect the distribution of violations by time of day. In the case of barrier-free HOV lanes on mainline freeways, the hours of operation are typically posted on roadside signs and there is a pronounced tendency for violations to concentrate heavily at the fringes of the operating period (see Section 5.2.1). In the case of pretimed ramp signals such as those in use in Los Angeles at the start of this study, ramp meters turn on automatically at a posted time each day, confronting potential violators with an active signal and rendering the excuse "I didn't know what time it was" virtually useless. In the case of traffic-responsive ramp meters such as those used in San Diego, moreover, there was no apparent tendency for violation rates to increase at the fringes of the morning operating period. Because meters on San Diego ramps respond to traffic conditions on the freeway, however, and turn themselves on automatically when congested conditions exist, the boundaries of the metering period vary from day to day. The highest violation rates on the traffic-responsive San Diego ramps appeared to peak on the hour, just before 7:00 a.m. and again just before 8:00 a.m. (see Reference 4), with the highest violation rate occurring during the five-minute interval between 6:55 and 7:00 a.m.

Officer Visibility. The visibility of the enforcing officer is an important consideration in evaluating the effectiveness of special enforcement activities. As discussed in Section 1.4.1, three levels of visibility were defined in classifying ramp bypass lanes:

Exhibit 3.4
MEAN RAMP VIOLATION RATES BY TIME OF DAY
LOS ANGELES RAMPS





- officer visible

- visibility queue-dependent

- officer not visible

The ultimate visibility of officers enforcing a ramp bypass lane depends on decisions made by a variety of individuals, ranging from designing engineers to the officers themselves. Observations of over fifty ramps made it apparent that landscaping and slope had as much to do with determining visibility as a ramp's design type (diamond, cloverleaf, etc.). In some cases, a visit from a landscape maintenance crew or a seasonal loss of foliage could cause a non-visible ramp to be reclassified as visible. Similarly, slight variations in meter placement along a slope could change a ramp's classification from visible to non-visible, or vice versa. Designers should attempt to examine each ramp from the point of view of the enforcing officer in making decisions regarding meter placements and bypass lane configuration.

On ramps where a patrol officer has some flexibility in selecting an enforcement position beyond the meter, the officer's choice of position may determine the relative visibility of enforcement activity. Officers interviewed regarding their choices in such situations failed to supply a consensus with respect to an optimum strategy. Some officers preferred to enforce from a position which was out of sight of potential violators, thereby maximizing the citations issued during a single enforcement stint. Other officers, however, preferred to stand in a position which maximized their chances of being seen by oncoming violators. The reasons given for the choice of a highly visible position were safety-related. As one officer explained, "drivers entering the freeway tend to look back over their shoulders to the left and veer slightly to the right, so that they are heading toward me without looking at me...I want to make sure that they see me in time to stop."

A comparison of the drop in violation rates and the residual impact of enforcement experienced under visible and non-visible conditions revealed slight but statistically insignificant improvements under conditions of non-visible enforcement. The table below displays the average reduction in violation rates experienced on a sample of ramp bypass lanes following each wave of special enforcement activity.

ENFORCEMENT IMPACTS BY RAMP VISIBILITY

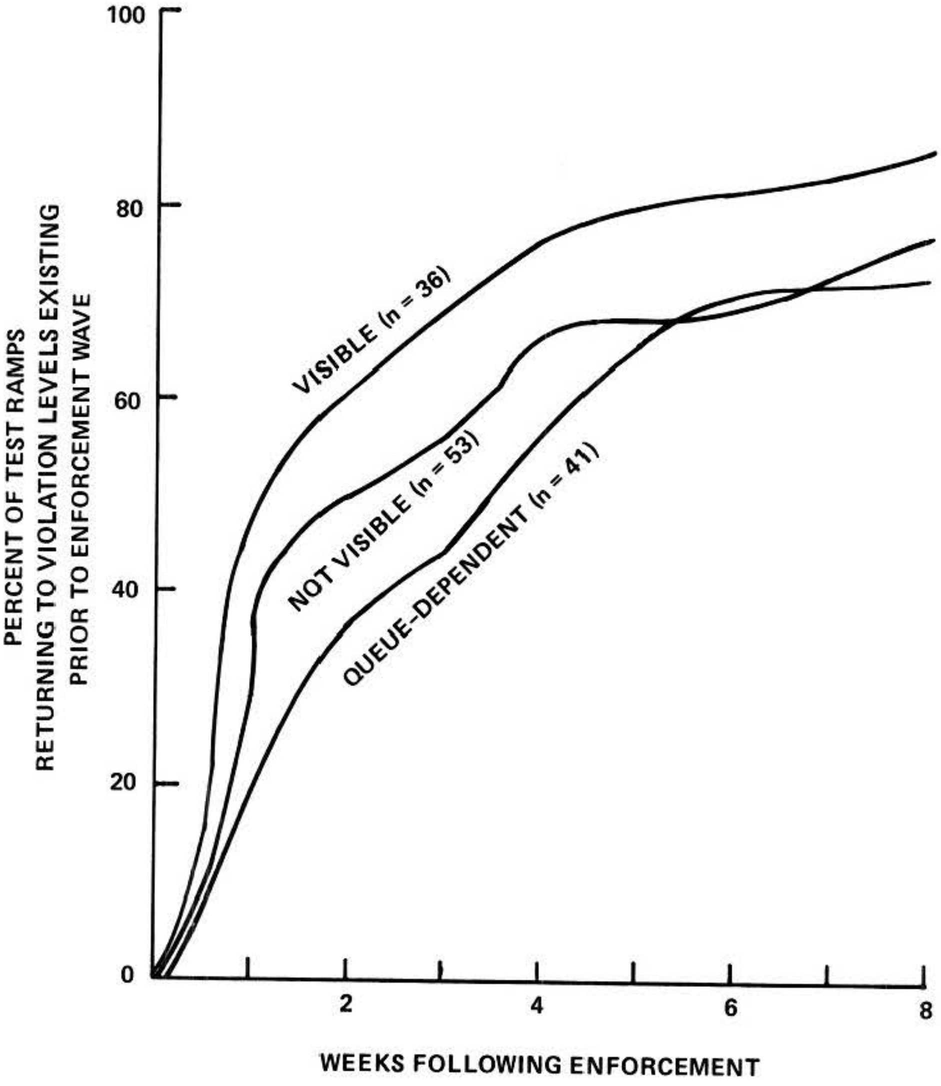
	RAMP CLASSIFICATION			
	Visible	Queue Dependent	Not Visible	Total
First Enforcement Wave				
Number of ramps sampled	12	10	15	37
Average Ramp Violation Rate (%)				
Before Enforcement	9.9	13.8	12.0	11.8
After Enforcement	6.8	9.1	8.1	7.9
Average Reduction (%)	31.3%	33.7%	32.8%	32.7%
Second, Third & Fourth Enforcement Waves				
Number of ramps sampled	24	31	38	93
Average Ramp Violation Rate (%)				
Before Enforcement	8.0	9.4	8.5	8.7
After Enforcement	7.1	7.7	7.4	7.4
Average Reduction (%)	10.9%	17.5%	13.0%	14.1%
All Four Enforcement Waves				
Number of ramps sampled	36	41	53	130
Average Ramp Violation Rate (%)				
Before Enforcement	8.6	10.5	9.5	9.6
After Enforcement	7.0	8.1	7.6	7.6
Average Reduction (%)	18.7%	22.8%	20.0%	20.6%

Thus the average reductions in violations following the four waves of special enforcement were slightly greater than average for ramps where the enforcing officers were not visible to potential violators until they had committed themselves irrevocably. However, the reduction rates for ramps on which the enforcing officers were fully visible were nearly as great, and the difference was not statistically significant (at the .05 level of significance).

The relatively visibility of the enforcing officer also had a slight but statistically insignificant effect on the residual impacts of enforcement. Exhibit 3.5 charts the composite residual enforcement impacts observed over the first eight weeks after all four waves of enforcement for ramps with different visibility classifications. When the ramps are grouped by various degrees of officer visibility, it appears that the residual impacts of enforcement lasted somewhat longer on ramps where enforcement was <u>not</u> visible to drivers until they passed the meter. Overall about three-quarters of these ramps returned to their initial violation levels during the post-enforcement period,`while 86% of those ramps where enforcement activities took place in full view of drivers entering the ramp returned to their pre-enforcement violation levels at least once during the eight weeks after enforcement. The corresponding figure for ramps where enforcement visibility depended on the queue length was 71.0%. The differences between the residual effects of visible and non-visible enforcement were most pronounced

Exhibit 3.5

RESIDUAL IMPACTS OF ALL FOUR WAVES OF SPECIAL ENFORCEMENT BY OFFICER VISIBILITY



following the first two waves of special enforcement.[2] After subsequent enforcement waves, over half of all ramps returned to their pre-enforcement levels within two weeks after special enforcement ceased, regardless of their visibility classification.

Although a longer residual impact on ramps with non-visible enforcement is not surprising, the differences observed following the four waves of enforcement were not found to be statistically significant. Intuitively, potential violators run a smaller risk of apprehension on ramps where enforcement is visible, since drivers can always tell whether an officer is present. On ramps where the geometric configuration prevents ramp users from sensing the presence of an officer until it is too late, violators run a higher risk of being ticketed and therefore presumably remain cautious for longer periods after special enforcement ceases. While the results of the four enforcement waves tend to support this intuitive relationship, the differences between the impacts of non-visible and visible approaches to ramp enforcement have been neither striking nor statistically significant.

From the standpoint of bypass lane design the findings of the current study suggest that the need to shield officers from the view of potential violators can be overemphasized. It is far more important that refuge areas be provided than that they be located out of the line of sight of potential violators. While it is desirable to shield refuge areas, it is not worth incurring significant additional expense to do so.

3.1.2 Impact of Violations on Freeway Performance

Few HOV projects outside of California have attempted to define explicit enforcement goals or "tolerable" violation rates. As reported in Reference 23, enforcement objectives have generally been described in loose qualitative terms involving "maintenance of the integrity of the HOV project." A few enforcement agencies with operational experience in enforcing HOV lanes have established specific enforcement objectives by defining a "tolerable violation rate." As Miller and Deuser point out, however, "In most cases the tolerable violation rate is defined as the violation rate currently being experienced on the project." (Reference 23)

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[2] Only 55.6% of those ramps where enforcement activities were classified as visible returned to pre-enforcement violation levels eight weeks after special enforcement, while three-quarters of those ramps where enforcement activities were not visible did so during the same period. On ramps where enforcement activities were classified as queue-dependent, 58.8% returned to pre-enforcement violation levels during the eight weeks after enforcement.

The data accumulated in this study have provided a number of insights into the effect of enforcement levels, freeway performance, and engineering design decisions on violation rates on California's HOV projects. But what of the effects of occupancy violations on freeway performance? At what point, if any, does the illegal use of an HOV lane threaten the safety of other motorists or the traffic-carrying capabilities of the freeway network itself? The answer to this question has a bearing both on the priority assigned to HOV lane enforcement and on the level of violations that can be tolerated before special enforcement activities are required.

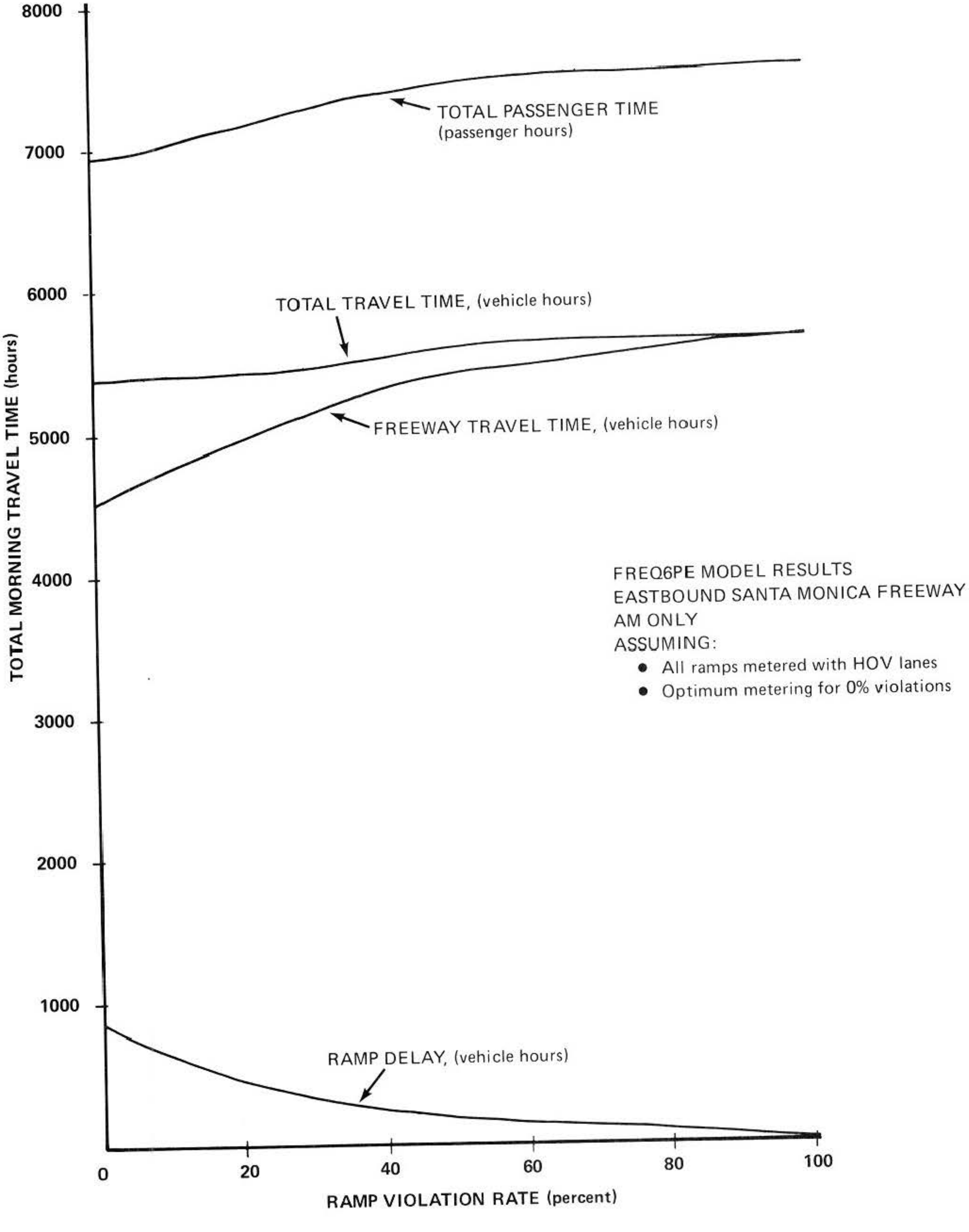
Some violators, of course, constitute a direct threat to the safety of other drivers. These are the weaving violators, peeking duckers, turning wormers, and startled stoppers discussed in Section 4.1, and they constitute a relatively small proportion (roughly 20%) of the drivers using the ramp bypass lanes illegally. Whether or not they pose a direct threat to safety, however, all violators represent an indirect threat to the time savings, accident relief, and other benefits obtainable through the use of metered ramp control. As more and more drivers violate bypass lanes, the effectiveness of the meters is diminished, and the investment in metered freeway control is wasted. A key question from the standpoint of the enforcing and planning agencies, then, is "how many violations can be tolerated before the integrity of the metering system is threatened?"

Approach. The answer to this question is heavily dependent on the characteristics of the individual roadway and the design of the metering system. To investigate the effect of violations on freeway performance, a single stretch of freeway was simulated and the relationship between violations and freeway performance was modeled using the FREQ6PE program developed at the University of California's Institute for Transportation Studies under the supervision of Professor Adolf D. May. (Reference 18)

The FREQ6PE program was used to model traffic flow on the eastbound Santa Monica Freeway (I-10) in Los Angeles during the morning peak period. Capacities of each segment of the freeway between the San Diego and Harbor Freeways were incorporated in the model, and current ramp flows were used as a basis for modeling the origin and destination patterns followed by drivers during the morning commute period. A linear programming optimization process was used to select a suitable metering strategy assuming every driver complied strictly with the ramp control plan (i.e., assuming a 0% ramp violation rate on all ramps). A sensitivity analysis was then undertaken in which ramp violation rates on all metered ramps were set at discrete intervals of 5%, 10%, 20%, 50%, and 100%.

Results. The results of the sensitivity analysis are summarized in the table below and plotted in Exhibit 3.6.

Exhibit 3.6
TRAVEL TIME vs. RAMP VIOLATION RATES



TRAVEL TIME AS A FUNCTION OF VIOLATION RATES
Eastbound Santa Monica Freeway -- Morning Peak Period

FREQ6PE MODEL RESULTS
ASSUMING ALL RAMPS METERED WITH HOV BYPASS LANES

Violation Rates (%)	Vehicle Travel Time (vehicle hours) Ramp Delay	Freeway Travel	Total	Total Passenger Time (passenger hours)
0	838	4563	5401	6953
5	731	4664	5395	6982
10	646	4772	5418	7040
20	474	4984	5458	7149
50	204	5422	5626	7458
100	0	5632	5632	7530

As the ramp violation rate increases from 0% to 100%, the vehicle time spent waiting daily in ramp queues drops from 838 vehicle hours to zero. The time spent traveling on the freeway itself, however, increases from 4560 to 5632 vehicle hours, as freeway congestion increases with weakening ramp controls. When ramp delays and freeway travel time are combined, the total freeway travel time rises from 5401 vehicle hours to 5632 vehicle hours, an increase of 4.2%. This corresponds to an 8.3% increase in passenger travel time, which rises from 6953 person hours to 7530 person hours as congestion increases and the effectiveness of HOV priority treatment vanishes with violations.

<u>Interpretation of Results</u>. If all metered ramps have HOV bypass lanes, the travel time registered under conditions of 100% violations reflects freeway operations in an unmetered state. The net effect of an optimum metering plan in the absence of violations, then, is to save 231 vehicle hours per day,[3] the difference between the 5632 vehicle hours experienced in the unmetered state, and the 5401 vehicle hours experienced under conditions of zero violations. As violations increase, this savings vanishes. For the modeled freeway, moreover, most of the savings in passenger and vehicle time have vanished by the time ramp violation rates reach 50%. A 50% ramp violation rate causes 97% of the vehicle time savings to disappear. It can be assumed that other benefits such as accident reduction and energy savings vanish at a comparable rate since they are tied to the same freeway flow conditions which govern travel time. Violation rates of 20% bring about a 24% reduction in vehicle time savings and a disproportionate 34% reduction in passenger time savings. On the other hand, violation rates below five percent have virtually no impact on vehicle travel time.

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[3] This modeled impact is consistent with empirical findings based on measurements taken before and after the installation of ramp metering projects. On five Los Angeles freeways which had ramp control installed with no additional roadway improvements, the net benefits realized averaged 298 vehicle hours per freeway per day. (Reference 12)

The results plotted in Exhibit 3.6 reflect conditions on a single specific freeway under the following critical operating assumptions:

1. A metering strategy is followed which optimizes passenger travel time under conditions of total compliance;

2. Priority entry for HOVs is provided on every metered freeway ramp.

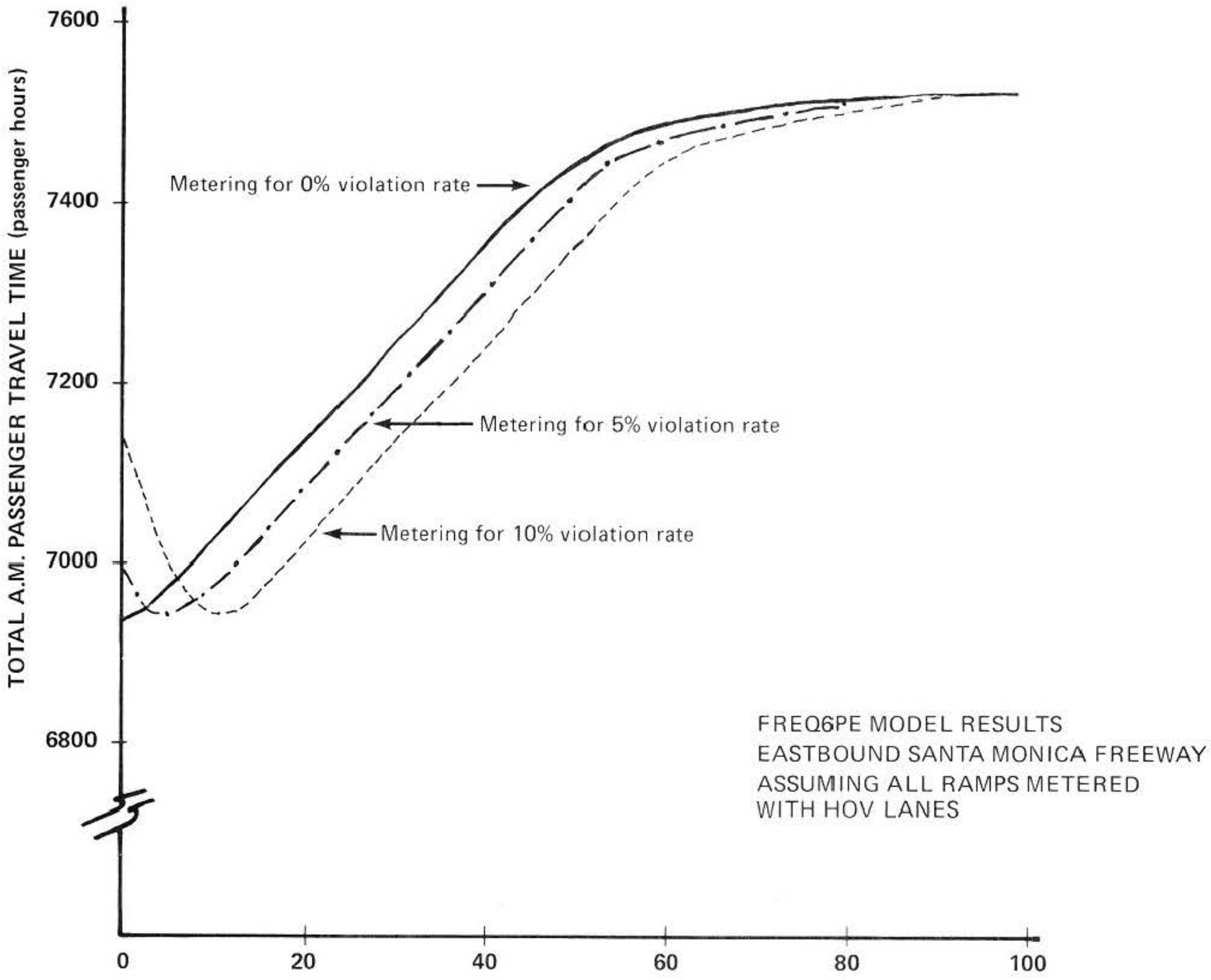
Regarding Assumption (1), if metering rates are less restrictive than those specified in the optimum strategy, the net benefits realized from the metering system will be reduced, but violations are still likely to have a disproportionate impact on these benefits. If metering rates are more restrictive than those specified in the optimum strategy, the time spent waiting in queues will increase and a limited number of violations may actually improve overall system performance, by reducing ramp waiting time without adversely affecting freeway flow. Once violations increase to the point where freeway flow is restricted, however, further increases will affect system performance adversely. This effect is plotted in Exhibit 3.7, which graphs the modeled impacts of violations on passenger travel time for three different freeway control strategies. The left-most curve repeats the passenger-time data of Exhibit 3.6, which reflects a metering strategy based on a zero violation rate. The middle curve shows the effect of a more restrictive metering scheme designed to produce optimum results with a five percent ramp violation rate, while the right-most curve shows the effects of metering to accommodate a 10% violation rate. Under the more restrictive control strategies, overall performance, measured in terms of travel time, will deteriorate if violation rates drop below the design value.

Regarding Assumption (2) above, in the event that priority entry is not provided on all metered ramps, the effect of violations on freeway performance is likely to be muted. Since the number of drivers violating meter restrictions by running the red light is relatively low, and since these violations tend to occur when traffic volumes are low and ramp queues are short, meter violations on ramps without HOV bypass lanes are not likely to affect the systemwide savings in time, accidents, and energy available from metered freeway control. So long as HOV occupancy violations are the only ramp violations likely to affect freeway performance, the adverse impacts of these violations may be reduced by providing fewer HOV lanes. While this statement may seem obvious, its application is less so. The impact of a single ramp's violations on freeway flow, travel time, and accident frequency will depend both upon the overall metering plan and the relationship of that ramp to freeway bottlenecks. It is possible that violations on certain restrictively metered ramps will have no impact on freeway flow, while violations on a few critically positioned ramps can negate most of the positive impacts of ramp metering.

Implications of Findings. The relationship of ramp violations to freeway flow is heavily dependent on the characteristics of the individual roadway, the number of ramps provided with bypass lanes and

Exhibit 3.7

PASSENGER TRAVEL TIME
as a function of
RAMP VIOLATION RATES
for
THREE RAMP CONTROL STRATEGIES



the metering strategy selected. In spite of the highly particular and complex nature of this relationship, a few general procedures may be adopted to limit the adverse impacts of ramp violations on freeway flow.

1. Incorporate violations in the design process. In the past, the prospect of ramp violations has generally been ignored by designers planning metering strategies and selecting individual metering rates. Designers should treat the possibility of violations explicitly and assume a violation rate of 5% will exist on all ramps provided with HOV bypass lanes. As a general rule, metering rates should be set to accommodate this level of violations. The levels of enforcement needed to drive ramp violation rates below 5% are generally prohibitively expensive. However, attempts to accomodate higher violation rates on all ramps in the design process are likely to result in excessive ramp delays and reduced system performance.

2. Identify critical ramps. Sensitivity analyses should be undertaken on each ramp to determine the impact of higher violation rates on freeway performance and travel time. On those critical ramps (generally those ramps just upstream of bottlenecks) for which violations have a disproportionate impact on freeway flow, two alternative courses of action are possible:

   a) The designer may build a larger safety factor into the metering rate for critical ramps. (That is, a set metering rate to accommodate violation levels in excess of 5%.)

   b) The designer may elect to omit HOV bypass lanes from critical ramps, thereby eliminating the adverse impact of a particular group of violations on freeway flow. Queueing delays on such ramps would be further reduced, as metering rates need not be set restrictively to accommodate HOV lane violations. However, the contribution of priority entry to improved passenger travel time would be lost, as would the incentive provided by the HOV lane.

Designers should evaluate the costs and benefits of each of these alternatives on a case-by-case basis in developing overall metering strategies.

3.1.3 General Design Concerns

Several basic concerns must be addressed in designing ramp bypass lanes. These include lane placement, separation, signing, metering, merging distance, storage capacity, and the need for a refuge area. This subsection views several of these concerns from the standpoint of their impact on enforcement and violation rates.

Refuge Areas. Refuge areas are essential for the safe and efficient enforcement of ramp bypass lanes. The ideal refuge area will be:

- located beyond the meter;
- out of the sight of potential ramp violators;
- shielded from the view of motorists on the freeway itself;
- in a position to provide a stationary officer with an adequate vantage point; and
- provided with ample storage space for apprehending and ticketing violators.

If, as is often the case, existing freeway geometrics make it impossible to meet all of these criteria, the officers must, at a minimum, be provided with a suitable vantage point and an adequate shoulder area for apprehending and ticketing violators.

Metering the HOV Lane. In San Diego, all HOV bypass lanes are metered, although at a less restrictive rate than the adjacent general traffic lanes. In Los Angeles, all but one of the HOV bypass lanes are unmetered. Proponents of metered HOV lanes argue that stopping vehicles in both lanes eases the merging process. Opponents argue that forcing the HOV lane to stop lessens the incentive for carpooling. There is little hard quantitative evidence to support or refute either of these positions. Ramp accident data are too variable to support an inquiry into merging problems, and although the time required to stop at the meter in San Diego lessens the advantage offered to carpool drivers slightly, both San Diego drivers and Los Angeles drivers wildly overestimate the savings afforded by HOV lane use. On six sample ramps in Los angeles, drivers estimated that they could save 3.8 minutes using the carpool lane, while the actual savings was 1 minute. In San Diego, drivers using two freeway-to-freeway connectors estimated that they would save 3.0 minutes using the carpool lane, while the actual savings was 45 seconds.

An examination of violation statistics provides no strong support for or against the metering of the HOV lane. Ramp violation rates are considerably lower in San Diego than in Los Angeles, but there are several other design and enforcement differences in San Diego which help to account for the lower rate. (Meters are traffic responsive, bypass lanes are newer, and there are more officers per bypass lane than in Los Angeles.) Occupancy violation rates on the only bypass ramp in Los Angeles with a metered HOV lane (Bundy Ave. on the Santa Monica Freeway) are comparable with those on other ramps installed at the same time. Meter violations are higher on ramps with both lanes metered, since there is no free path around the red light. Roughly 1% of all drivers on ramps with unmetered bypass lanes violate the meter by running the red light or following another car through the green phase. On San

Diego ramps with the bypass lane metered, the meter violation rate increases to 1.4%. This is still significantly lower than the meter violation rate of 3.8% recorded on those metered ramps in Los Angeles having no bypass lane to tempt would-be meter violators (see Study Design, Reference 3).

From the standpoint of enforcement, occupancy violators in unmetered bypass lanes tend to be traveling much faster past the stationary officer than violators who have to stop for a red signal. Thus the enforcement activity itself is somewhat simpler and safer when the bypass lane is metered.

Traffic-Responsive Meters. Ramp meters in the San Diego area are all traffic-responsive, while those in the Los Angeles area at the time of the study were primarily pre-timed.[4] While ramp violation rates in San Diego are significantly lower than those in Los Angeles, there are several other factors contributing to this difference (see above discussion of metered bypass lanes). The use of traffic-responsive meters can be expected to reduce the total number of occupancy violations during the morning and evening peaks, simply because the meters will not usually be operational during the full three- or four-hour period when pre-timed meters are operating. San Diego bypass lanes are free from the rash of early-morning, late-evening violations characterizing pre-timed Los Angeles meters (see Section 3.1.1) because the traffic-responsive meters are generally inoperative during these time periods. For the same reasons, meter violation rates are lower in San Diego than on pretimed Los Angeles ramps with no bypass lanes. There is no evidence to suggest that ramp violation rates during periods of meter operation will differ with pre-timed and traffic-responsive meters. Violations on Los Angeles ramps should be monitored as traffic-responsive meters are installed to determine whether any change occurs.

With traffic responsive meters, it is essential that some mechanism be devised so that the officer downstream from the meter can tell whether or not the meter is operational, particularly if the HOV restriction is tied to meter operation. Downstream awareness can be supplied with lighted signs, as in San Diego, or with rear-view lights such as those installed on certain Los Angeles ramps.

Occupancy Requirements. CALTRANS guidance for ramp meter bypass lanes states that: "the carpool requirement for ramp meter bypass lanes should be determined after an analysis of each installation. Two occupants per vehicle is the requirement for most bypasses in operation throughout the state today." (Reference 13) The Guadalupe Expressway, which requires three-person carpools, is an exception to this rule. From the standpoint of enforcement, consistency is desirable, particularly for like projects within a single region. Officers and observers also find it easier to distinguish the difference between a

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[4] Los Angeles meters are currently being converted to the traffic responsive mode.

single occupant and two persons in a moving vehicle than to distinguish between vehicles with two persons and vehicles carrying three people. From the standpoint of violator identification, then, a two-person requirement is somewhat easier to enforce.

Left Hand vs. Right Hand Lanes. Of the 162 ramp bypass lanes operating in Los Angeles and San Diego, 113 (70%) have HOV lanes on the left, while 49 (30%) use the right lane for preferential treatment. The selection of left hand or right hand lanes for preferential treatments depends on a number of site-specific parameters, including merging conditions, signal position, refuge area location, and ramp access problems. A few considerations in the selection process we addressed below:

a) In the absence of other considerations on ramps with unmetered HOV lanes, the HOV lane should be on the left to allow the slower metered traffic to merge with HOV traffic on the left in the customary fashion. As noted in Reference 22, this "eliminates the problem of general lane drivers being wary of traffic from both sides."

b) Reference 22 also suggests that on curved ramps, unmetered HOV lanes should generally be on the outside of the general lane. The authors reason that "...this gives the non-stop HOVs a lower degree of curvature, but more importantly, metered lane traffic has a clearer rear view of the HOV lane, thus reducing the hazard of their changing lanes.

c) When the refuge area for enforcement occurs before the two streams of traffic have merged, left-hand HOV lanes often require officers to step through a moving lane of general traffic to attract a violator and wave him back through the same traffic to the refuge point, which is generally located on the right hand side of the roadway. Although the general traffic lane which the officer must cross is moving relatively slowly, drivers in that lane tend to be looking over their left shoulders to accomplish the merging process. In such a situation, a right-hand HOV lane improves the safety of both the enforcing officer and the violator attempting to reach the refuge area.

d) When vehicles may turn left from surface streets onto a ramp, the left lane is preferred for HOV treatment. This reduces weaving conflicts, but can cause some left-turning vehicles to be trapped in the HOV lane if the metered lane overflows. This problem is discussed in more detail in the following subsection.

3.1.4 The Problem of Trapping Ramps

One of the most serious questions to be addressed in designing carpool bypass lanes for metered ramps is whether single-occupant autos may be inadvertently forced to use the bypass lane under certain conditions. Ramp designs which have the potential for inducing violations are designated in this report as "trapping" ramps, since otherwise law-abiding drivers are sometimes trapped against their will in lanes reserved for buses and carpools. The most common type of trapping ramp configuration is one in which left turns are permitted from a surface street onto a freeway ramp which reserves its left-hand lane for buses and carpools. When the queue in the right-hand lane on such a ramp overflows onto the surface street, vehicles making left turns onto the ramp can be forced into the carpool lane, whether or not they are qualified to use it. Exhibit 3.8 illustrates such a situation.

Trapping ramps pose a special problem for enforcement personnel. The enforcing officer is seldom in a position to judge whether or not a driver observed using the lane illegally did so deliberately or was trapped by circumstances and recalcitrant drivers unwilling to yield their position in the metered queue. As a consequence, some officers interviewed during this study have expressed a reluctance to enforce trapping ramps, since the culpability of the offender is not always clear. One officer, speaking of the Fletcher Parkway ramp in San Diego, said he felt that citations issued to drivers who found themselves in the bypass lane on that ramp weren't "good tickets."

The extent to which drivers can be trapped in bypass lanes against their will depends on a number of factors, including the ramp's storage capacity, the length of the metered queue, the number of vehicles attempting to turn left onto the ramp, and the experience of the drivers themselves. In an attempt to shed additional light upon the effect of this important aspect of ramp design on violations, and the impact of enforcement in reducing violation rates on trapping ramps, several Los Angeles ramps having the potential for trapping unwilling drivers were singled out for special study. Of the sample ramps included in the current study the following Los Angeles ramps were judged to be capable of trapping drivers in the bypass lane:

Exhibit 3.8

TRAPPING RAMP EXAMPLE

The sports car turning left onto the National/Robertson ramp leading to the Santa Monica Freeway is unable to enter the queue of autos in the right turn lane. He has no choice but to use the reserved left lane illegally if he is to vacate the intersection before the left-turn signal changes.

A SAMPLING OF POTENTIAL TRAPPING RAMPS

Los Angeles

Freeway		AM/PM	Auto Storage Capacity	% of Time Capacity is Exceeded* Before Enforcement	 After Enforcement
LA5	Pasadena	PM	20	0	0
LA10	Bundy	AM	20	9.1	18.3
LA10	Crenshaw	PM	27	0	0
LA10	National	AM	15	10.9	36.0
LA10	Venice	AM	14	18.9	38.2
LA10	Western EB	AM	16	0	0
LA10	Western WB	PM	22	0	0
LA101	Coldwater Canyon	AM	16	16.9	9.2
LA101	Woodman	AM	17	6.7	1.6
LA405	Moraga	PM	10	15.5	24.0
LA405	Olympic/Pico	PM	12	3.0	20.3

*Based on observations taken every minute during the metering period on at least two days before and after enforcement actions.

Vehicles making left turns from surface streets onto each of these ramps could conceivably be trapped in the carpool lane when the ramp overflows. As a practical matter, however, observation of ramp operations showed that the storage capacity was never exceeded on four of the identified ramps: Pasadena on LA 5; and Crenshaw, Western EB and Western WB on LA10. Although unwitting drivers could theoretically be trapped into violation on these four ramps, the ramp overflows needed to set the trap rarely occur in practice. Accordingly, these four ramps were not subjected to further analysis. To investigate the extent of the trapping problems on the remaining seven ramps, each of these ramps was observed during peak-hour operation, and violation rates were recorded before and after special enforcement. The results of these observations are summarized in Exhibit 3.9, which lists the percentage of time during each metering period the ramp was filled to capacity, the relative number of vehicles turning left onto the ramp, and violation rates before and after the first wave of special enforcement.

Most of the statistics in Exhibit 3.9 fit a common pattern and support one's intuition regarding the likely levels of violations on trapping ramps, but some insights can be gained from a consideration of the pattern itself and those exceptions to it. As might be expected, violation rates are almost universally higher when the ramp is filled with waiting cars. Those few instances in which higher violation rates were recorded with the ramp operating below capacity were not found to be statistically significant. Since little correlation between violation rates and queue lengths has been found on ramps in general (see Section 3.1.1) it can be inferred that the trapping design increases the level of violations on a ramp. For the most part, however, violation levels on trapping ramps generally respond to enforcement efforts. On six of the seven ramps studied, special enforcement efforts lowered violation rates significantly, and the rates

Exhibit 3.9

VIOLATION RATES ON TRAPPING RAMPS

					RAMP VIOLATION RATE						
FWY	RAMP	Enforcement Phase	% Time Ramp is Full		Ramp Full		Ramp Not Full		Total	Residual Enforcement Impact (weeks)	Trapping Potential (% of left turns)
LA10	Bundy	Before	9.1%	S	14.7		17.7	S	15.1		
		After	18.3%		8.8		9.9		9.4	over 8	51.6%
						S					
LA10	National	Before	50.9%	S	19.5		13.1	S	16.2		
		After	36.0%		13.6		9.1		10.7	over 8	18.6%
						S					
LA10	Venice	Before	18.9%	S	19.6		14.4	S	14.8		
		After	38.2%		8.8		6.7		7.3	over 11	11.7%
						S					
LA101	Coldwater Canyon	Before	16.9%	S	11.0		6.4	S	7.1		
		After	9.2%		6.4		5.1		5.2	over 11	47.0%
						S					
LA101	Woodman	Before	6.7%		13.1		8.3	S	8.7		
		After	1.6%		*		5.1		5.1	over 11	48.7%
LA405	Moraga	Before	15.5%		14.5		14.8		14.7		
		After	24.0%		14.3		14.9		14.7	1	92.4%
LA405	Olympic/Pico	Before	3.0%		*		14.1	S	14.0		
		After	20.3%		8.5		7.9		7.9	over 8	49.7%

Legend:

* : Ramp was not full often enough to permit meaningful measurements of violation rates to be made.

$\overbrace{\qquad}^{S}$: Statistically significant difference between measurements with ramp full and not full.

S { : Statistically significant difference between measurements before and after enforcement.

remained below pre-enforcement levels for at least eight weeks after these efforts ceased.

The single exception to these observations, the Moraga ramp on the San Diego Freeway, provides some insight into the relative importance of storage capacity and turning movements on the response of trapping ramps to enforcement activity. On the Moraga ramp, special enforcement failed to reduce violation rates significantly, and violation rates returned to normal within one week after special enforcement ceased. But the Moraga ramp operations differ in one important respect from the other trapping ramps being observed. On Moraga, nearly every auto entering the ramp does so after making a left turn off Sepulveda Boulevard. This left turn traps many cars in the carpool lane when the short (ten-car) storage capacity of the ramp is exceeded. Thus the impact of a trapping ramp on enforcement and violations depends not only on the amount of time that ramp storage capacity is exceeded, but even more on the relative number of cars making the turning movement which springs the trap.

On two of the trapping ramps studied, the Venice and National ramps on the Santa Monica freeway, overflow conditions were more prevalent than on the Moraga ramp. However, relatively few cars entered these ramps by making the left turn movement which would trap them in the carpool lane. (Less than twenty percent of the cars entering these ramps did so after making a left turn.) Violation rates on these ramps were considerably more responsive to special enforcement than the corresponding rates on the Moraga ramp. Personal observation of the ramps in operation suggests that this phenomena can be traced to driver behavior as well as to the laws of probability which bring left-turning vehicles into contact with an overflowing queue. Drivers in the overflowing single-occupant queue appear willing to make room for one isolated vehicle attempting to turn left into the queue. When more than one vehicle is attempting to enter the queue, however, the slow movement of the queue itself, coupled with the unwillingness of most drivers to let more than one vehicle into line ahead of them, combines to leave the second and subsequent left-turning vehicles with no choice but to use the carpool lane illegally or remain hung up in the path of oncoming autos.

On most of the ramps with trapping characteristics, relatively few vehicles actually entered by way of the trapping path, and violation rates on these ramps proved responsive to enforcement. On the Moraga ramp, however, enforcement doesn't work and doesn't last because nearly every car entering the ramp does so in a way that can lead it to be trapped in the carpool lane when more than ten cars are waiting in the metered queue.

Several adjustments have been suggested to improve the operations of ramps with potential trapping properties:

1. Adjust metering rates to minimize the length of time the queue overflows.

2. Restrict left-turning movements to carpools and buses during meter operating hours.

3. When a traffic light exists at the ramp entrance (as in Exhibit 3.8), position the stop line for right-turning vehicles in the overflow queue far enough back to leave a gap for left-turning vehicles. Also, consider prohibiting right-turn-on-red movements.

4. Eliminate bypass lanes on trapping ramps.

Suggestion (1) through (3) can alleviate trapping problems under certain conditions. Suggestion (2), in particular, was tried with some success on six Santa Monica Freeway ramps during the controversial Diamond Lane demonstration. In cases such as the Moraga ramp, however, where a preponderance of the vehicles entering the ramp can potentially be trapped in the carpool lane, it is probably best to eliminate carpool restrictions and open the lane itself to general traffic. This solution was followed in the case of the Fletcher Parkway ramp in San Diego.

Special Striping

Background. The signing and marking of preferential lanes is one engineering design feature potentially capable of influencing both violations and the public perception of HOV projects. In March of 1979, CALTRANs instituted a set of uniform standards for the signing and marking of bus and carpool lanes throughout the state (see Exhibit 3.10). Prior to that time, individual jurisdictions exercised a certain degree of flexibility in designating such lanes. In particular, a few jurisdictions hesitated to use the diamond symbol to avoid being associated with the ill-will generated by the Santa Monica Freeway Diamond Lane project. (Reference 6)

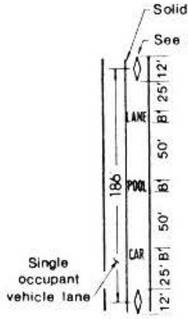
In the process of establishing uniform statewide standards, CALTRANS tested different signing and striping possibilities in a few locations. In March and April of 1979, CALTRANS District 07 in Los Angeles began experimenting with bolder striping patterns for delineating ramp bypass lanes. These patterns, which consist of bold stripes painted to form a continuous pattern of intersecting diamonds, were installed on four bypass lanes in southeastern Los Angeles (see Exhibit 3.11). The four lanes were part of a broader ramp metering project designed to control traffic entering the eastbound and westbound Artesia Freeway (Route 91) between Interstate Routes 7 and 5. Thirty-eight ramps were metered along this stretch of freeway, and bypass lanes were installed on seventeen ramps. Thirteen of the bypass lanes received conventional signing and striping, while the following four ramps were treated with the more distinctive diamond pattern, in addition on conventional markings:

SHEET NO.	TOTAL SHEETS
1	3

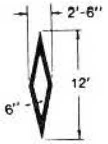
CHIEF, OFFICE OF HIGH OCCUPANCY VEHICLE PROGRAM
REGISTERED CIVIL ENGINEER NO. 12188
APPROVED FEB. 28, 1979

CARPOOL SIGNING AND PAVEMENT MARKING NOTES

1. Two advance carpool signs, R94, should be installed on local streets when striped for mandatory right turn.
2. Two or more carpool signs, R33B, should be installed on local streets (with concurrence of local agency) wherever left turns are restricted to carpools during the peak hours.
3. Two carpool signs, R91, should be installed on short on-ramps with one " ◇ CARPOOL LANE ◇ " pavement marking.
4. Four or more carpool signs, R91, should be installed on extra long on-ramps with two or more " ◇ CARPOOL LANE ◇ " pavement markings.
5. On short on-ramps, spacing shown in Detail A may be reduced.
6. Sign and pavement marking details shown on this sheet should be used wherever feasible. Exceptions and proposed experimentation with other signs and marking should be reviewed in advance by Headquarters Traffic.
7. The bus-carpool lane on a freeway on-ramp may be either on the left or the right side.
8. Additional required signs and markings are shown in Traffic Manual Section 4-05, Ramp Terminal Signing.



DETAIL 'A'
NO SCALE



DETAIL 'B'

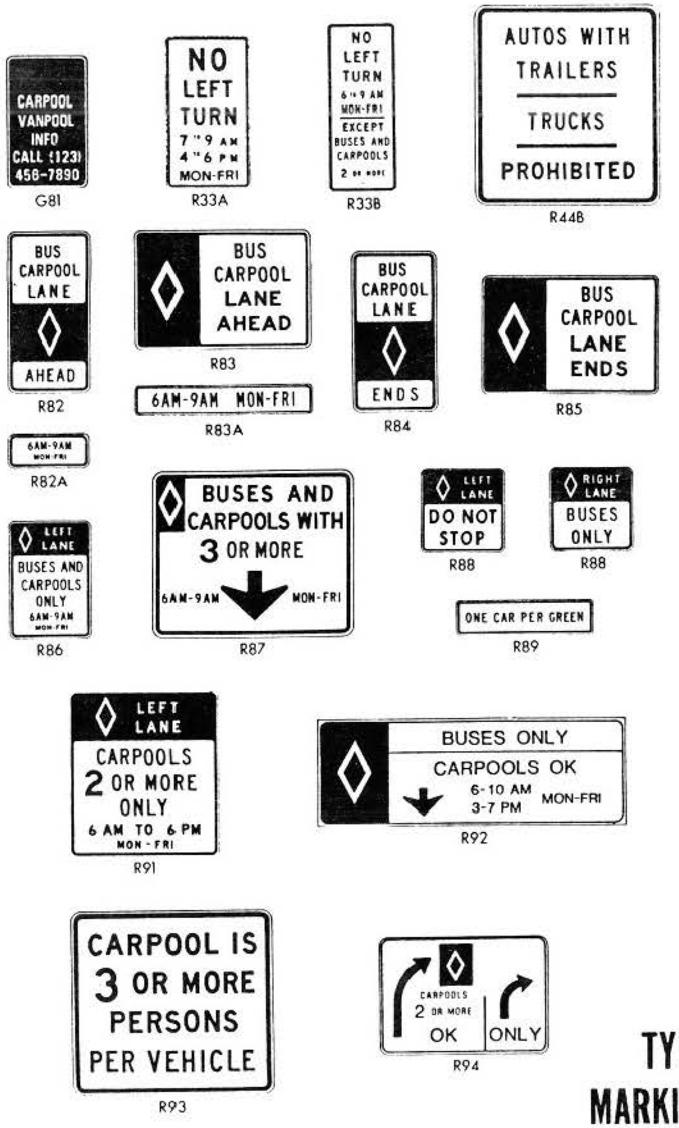


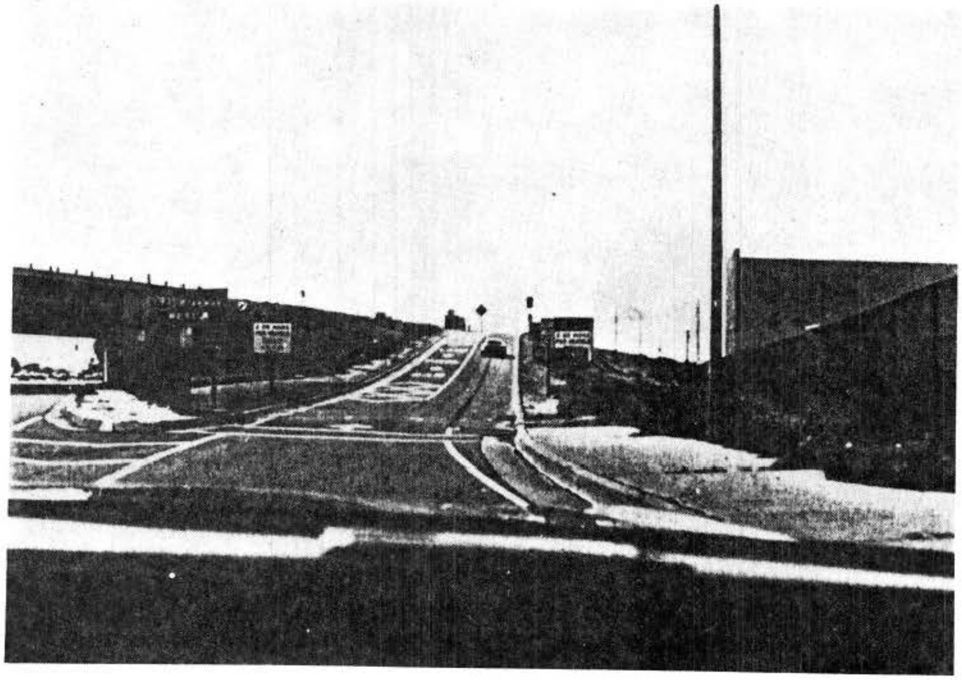
Exhibit 3.10

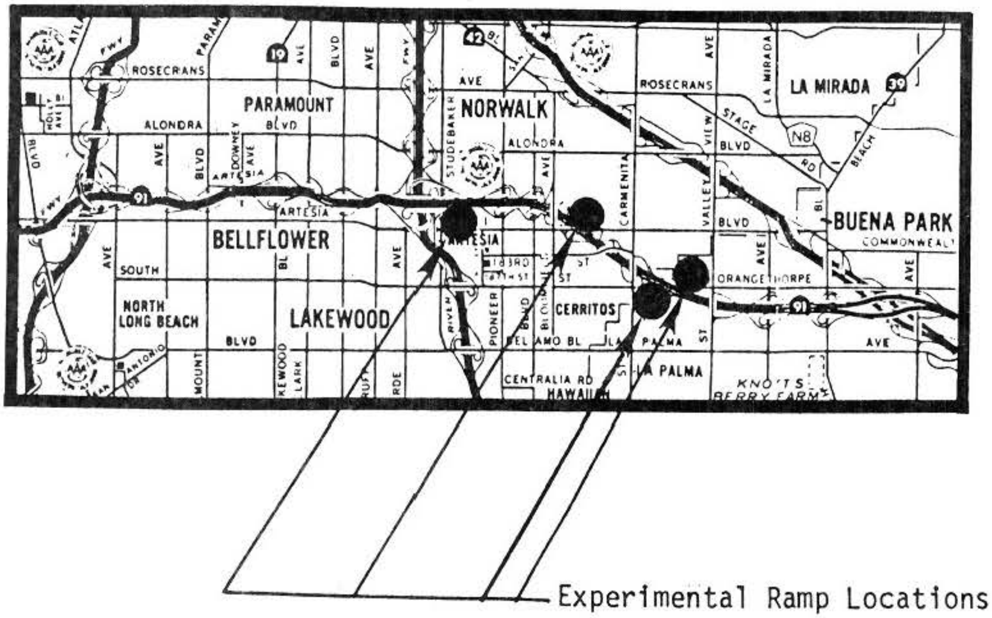
TYPICAL SIGNING AND PAVEMENT MARKING FOR BUS AND CARPOOL LANES

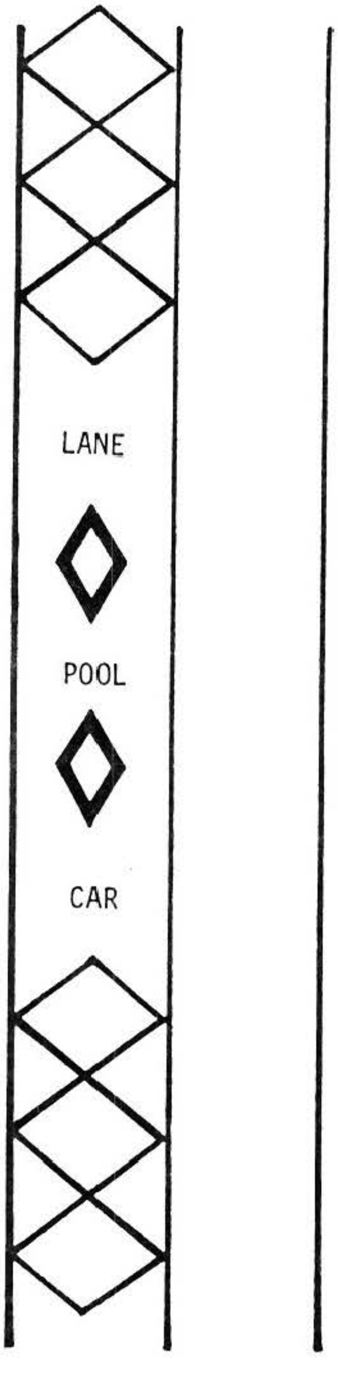
REV 8-14-80

Exhibit 3.11

EXPERIMENTAL CARPOOL LANE STRIPING
(Orangethorpe Ave. Ramp to Westbound Route 91, Orange County)







RAMPS WITH SPECIAL STRIPING

Hours of Operation	Ramp	
0600 - 0900	Orangethorpe Ave.	OR 91 Westbound
0600 - 0900	Artesia Boulevard	LA 91 Westbound
1600 - 1800	Studebaker Road	LA 91 Eastbound
1600 - 1800	Orangethorpe Ave.	OR 91 Eastbound

Exhibit 3.11 maps the location of these ramps and shows the special striping patterns as it appears on the Orangethorpe Ave. ramp entering Westbound Route 91.

Comparison Plan. The initial plan for analyzing the effects of special striping was devised by CALTRANS prior to the start of the current study. Under this plan, four new ramp bypass lanes with conventional striping were selected as control ramps to be used as a comparison base against which the effects of special striping could be measured. The four original control ramps are listed below:

CONTROL RAMPS WITH CONVENTIONAL STRIPING

Hours of Operation	Ramp	
0600 - 0900	NB Lakewood Blvd.	LA 91 Westbound
0600 - 0900	Downey Avenue	LA 91 Westbound
1500 - 1800	Bellflower Blvd.	LA 91 Eastbound
1500 - 1800	SB Lakewood Blvd.	LA 91 Eastbound

The comparison plan followed by CALTRANS tracked violation rates over the first six months of operation on each of the four control ramps and the four sample ramps with special striping. When the current study was initiated, approximately one year after the ramp bypass lanes were opened, an attempt was made to continue this comparison plan by applying special enforcement to a subset of ramps with special and conventional striping. Special enforcement was tested on the two Orangethorpe Avenue ramps with special striping, and on the NB Lakewood Avenue control ramp. During the first wave of special enforcement, each of these ramps received the attentions of one CHP officer two days per week for one month. Two complications arose to prevent the continued use of the orginal group of four special ramps and four control ramps during the first wave of special enforcement.

1. The HOV bypass lane on the control ramp on SB Lakewood Blvd. was eliminated; and

2. Continuing meter malfunctions on the Artesia ramp with special striping caused this ramp to be dropped from the study design.

To make up for the loss of the control ramp on SB Lakewood, one other Route 91 ramp, the Cherry Avenue on-ramp, was added to the control group. CALTRANS had observed violation rates on this ramp on two occasions over its first year of metered operation.

Overview of Results. Composite violation rates for ramps with and without special striping are summarized below as a function of time and enforcement policy. Details of the violation rates recorded for individual ramps may be found in Reference 5.

RAMP VIOLATION RATES
(Route 91 Ramps with and without special striping)

	ROUTINE ENFORCEMENT				SPECIAL ENFORCEMENT	
MONTHS AFTER OPENING:	1 to 3 MO	4 to 6 MO	12 to 14 MO	20 to 22 MO	14 to 18 MO	
					DURING	AFTER
Ramps with Special Striping	4.0%	5.8%	8.0%	9.1%	5.9%	5.5%
Ramps with Conventional Striping	10.0%	10.0%	10.3%	8.0%	5.6%	4.6%
Is Difference Statistically Significant?	YES	YES	YES	NO	NO	YES

As shown above, ramps with special striping had significantly lower violation rates than ramps with conventional striping during the first six months of bypass lane operation. As time went on, the deterrent effect of special striping apparently diminished, and after twenty-two months of operation, comparison tests showed no significant difference (at the .05 level of significance) between violation rates on routinely enforced ramps with and without special striping. Violation rates dropped appreciably on each of the three ramps receiving special enforcement and the presence or absence of special striping apparently had little impact on violations during and after the first enforcement wave.

Comparison Results: The Early Months. Observations made by CALTRANS leave little doubt that special HOV lane striping had a deterrent effect on violations during the early months of ramp operation. Following eleven days of observation on different ramps during the first three months of ramp operations, the lowest daily violation rate observed on any of the four control ramps was higher than the highest violation rate recorded on any ramp with special striping.

Over the first six months of operation, violation rates on ramps with special striping were only half as high as rates on ramps with conventional striping (5% vs 10%), and statistical tests[5] left little doubt that these differences were statistically significant.

Comparison Results: Long-Term Operation. After six months of operation, the deterrent effect of special striping began to diminish. Although tests showed a statistically significant difference between violation rates on ramps with and without special striping after twelve months of operation, the magnitude of the difference (8.0% vs. 10.3%) was less than that detected in the early months of operation. After twenty-two months, moreover, comparison tests showed no significant difference between violation rates on routinely enforced ramps with and without special striping. Although these longer-term results were obtained on a diminished sampling of ramps (ramps receiving special enforcement were removed from the sample, as were the malfunctioning Artesia ramp and the defunct bypass lane on SB Lakewood Avenue), it seems clear that the early deterrent effects of special striping tend to disappear with time.

Comparison Results: Special Enforcement. Violation rates dropped appreciably on each of the three Route 91 ramps included in the first wave of special enforcement. During the actual time of enforcement, violation rates were equal on ramps with and without special striping. In the two months following special enforcement, violation rates were slightly higher on the two Orangethorpe ramps with special striping than on the conventionally striped NB Lakewood ramp. There was no indication as a result of the first wave of enforcement that the combination of special enforcement and special striping was any more effective in reducing violations than the combination of special enforcement and conventional striping. A composite summary of violation rates for all combinations of special and routine enforcement and special and routine striping appears below.

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[5] The binomial test for the difference between two proportions, applied at the .05 level of significance.

RAMP VIOLATION RATES
(14 to 22 months after ramp opening)

	AFTER SPECIAL ENFORCEMENT	ROUTINE ENFORCEMENT
SPECIAL STRIPING	Orangethorpe AM Orangethorpe PM 5.5%	Studebaker PM 9.1%
CONVENTIONAL STRIPING	NB Lakewood AM 4.6%	Downey PM 8.0%

3.1.5 Pylons for Lane Separation

In a further attempt to determine the impact of lane demarkation on violation rates, candlestick delineators were installed between the bypass lane and the metered lane on five sample Los Angeles ramps. The five ramps included two with special striping, as indicated below.

SAMPLE RAMPS USING PYLONS FOR BYPASS LANE SEPARATION

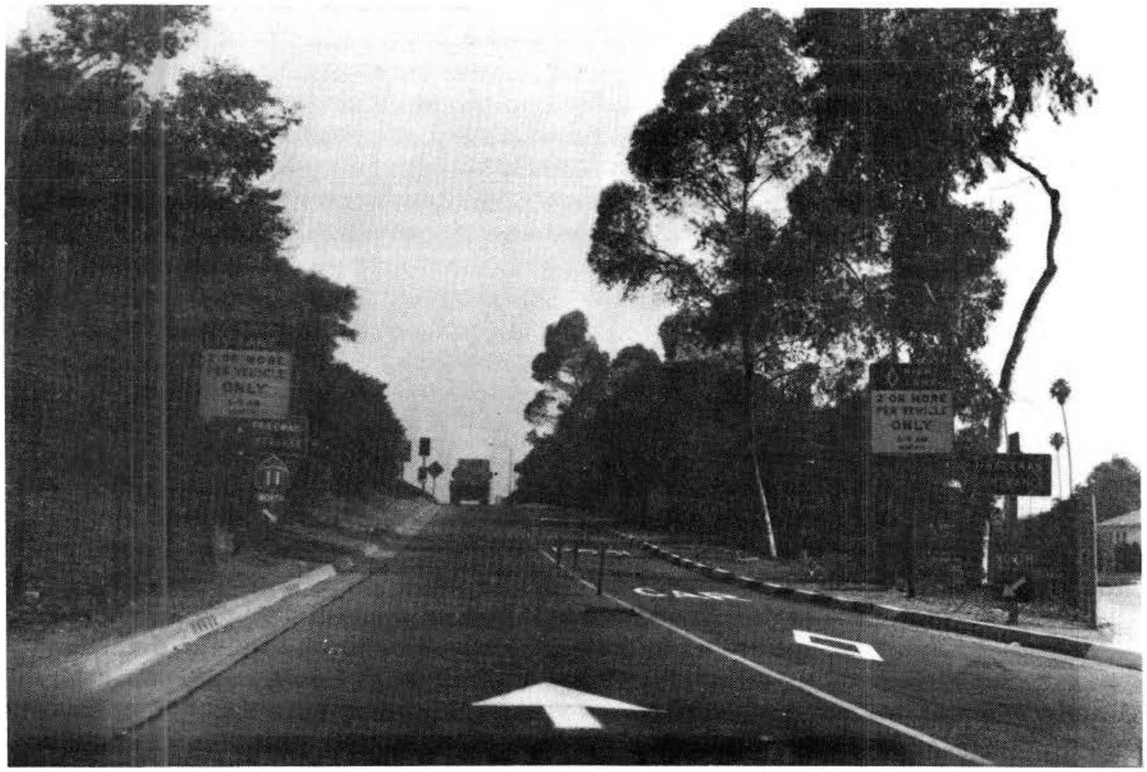
TIME	RAMP	FREEWAY	STRIPING	ENFORCEMENT
PM	Euclid	OR405	Conventional	Routine
PM	Bristol	OR405	Conventional	Routine
PM	Orangethorpe	OR91	Special	Special
AM	Florence	LA11	Conventional	Special
AM	Studebaker	LA91	Special	Routine

Exhibit 3.12 summarizes the ramp violation rates before and after the pylons were installed. Two ramps, Florence (LA11) and Orangethrope (LA91) had received special enforcement prior to the installation of pylons, while the three remaining ramps had been exposed only to routine enforcement. On the two sample ramps previously exposed to special enforcement, no significant difference was found in ramp violation rates before and after the pylons were installed (an average of 12.9% vs. 13.6%). As pylons were put up quicker than anticipated, no "before" measurements were made on two of the ramps receiving routine enforcement (Euclid and Bristol on OR405). On the third routinely enforced ramp, Studebaker on LA91, the installation of pylons did not seem to have any effect on ramp violation rates. Ramp violation rates went up slightly from 4.8% to 5.8% following the installation. On the basis of this experiment, it appears that the use of pylons to separate carpool and general traffic lanes has no impact in reducing ramp violation rates.

In addition to recording violation rates, CALTRANS workers recorded pylon loss over the first two months following installation. Exhibit 3.13 graphs the life expectancy of the pylons on the five sample ramps over this period. Overall life expectancy of pylons is short. Only

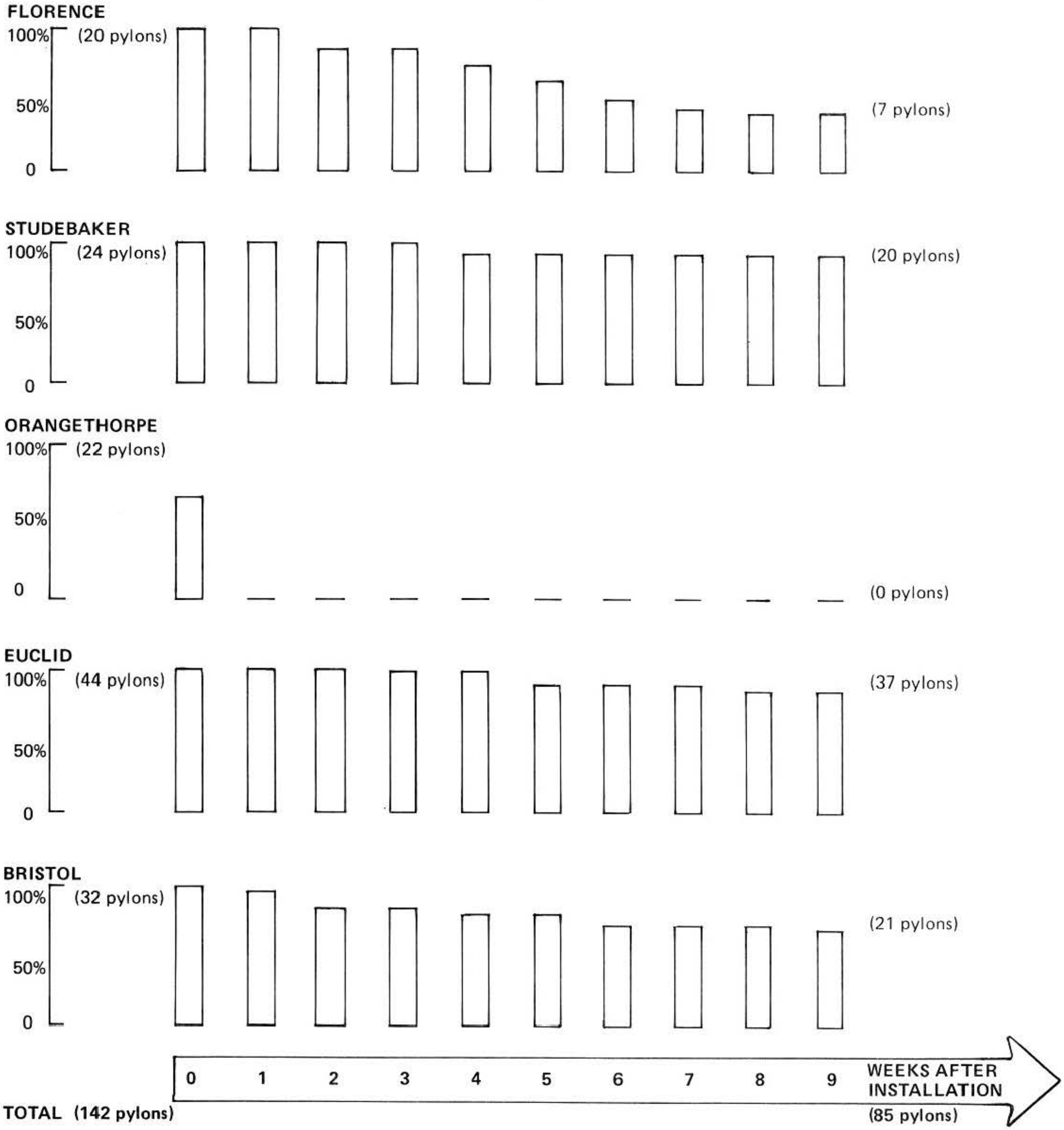
Exhibit 3.12

BYPASS LANE SEPARATION



RAMP VIOLATION RATES					
Ramps with Special Enforcement			Ramps with Routine Enforcement		
	Before Pylons	After Pylons		Before Pylons	After Pylons
Florence LA 11	17.2%	18.5%	Euclid OR 405	–	4.7%
Orangethorpe OR 91	5.1%	5.3%	Bristol OR 405	–	25.9%
			Studebaker LA 91	4.8%	5.8%

Exhibit 3.13
PYLON LIFE EXPECTANCY ON RAMP BYPASS LANES



sixty percent of the pylons were left nine weeks after installation. In the case of the Orangethorpe ramp, all pylons were knocked down within the first week of installation.

Since the cost of installing a signle row of pylons amounts to $1,000 per ramp, approximately $3,000 would be required to install, maintain, and replace pylons over a year of ramp operation. This amount is a high price to pay for an ineffective deterrent, particularly when an equivalent amount can purchase a level of enforcement which has been demonstrated to be effective in reducing violation rates (see Section 6.1.2). Since repeated installations of pylons are hazardous for maintenance crews, moreover, the use of candlestick delineators does not appear to be a good investment on ramp bypass lanes.

3.2 MAINLINE HOV LANES

In the case of mainline HOV lanes, the design options analyzed were chiefly to those already in place on California freeways: Marin 101, Alameda 580, and the San Bernardino Busway. Certain elements of design caused these projects to differ markedly with respect to the ease and effectiveness of enforcement. Chief among the design elements affecting enforcement and violations were the hours of operation, lane separation, and the availability of a refuge area.

3.2.1 Hours of Operation

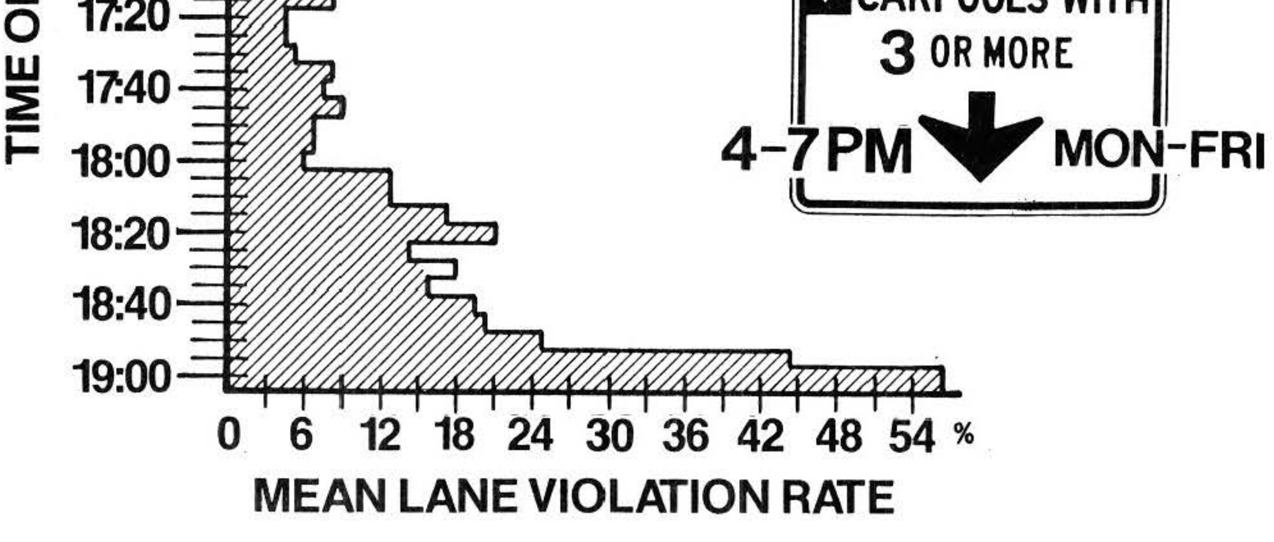
Impact of time of day on violations. Exhibit 3.14 traces violation rates as a function of time of day for the evening operating hours on Marin 101. The exhibit shows clearly that the preponderence of violations occur at the fringes of the operating hours, just after restrictions come into play at 4:00 p.m. and just before they are removed at 7:00 p.m. A similar phenomenon was observed during the morning operating hours on Marin 101, and during both morning and evening hours on the ill-fated Santa Monica Freeway Diamond Lanes. (Reference 6) Presumably, motorists on the road at the legal changeover times are either unaware of the time or lazy about obeying the law so close to the time at which they could use the lane legally.

In contrast with Marin 101 and the Santa Monica freeways, occupancy violations on the San Bernardino Busway show no tendency to cluster at the fringes of the operating period. Violations during the evening operating hours tend to be symmetrically distributed about the five o'clock peak, while violations during the morning rush hour occur predominently during the early hours of operation, with 34% of all morning violations taking place in the one-hour period between 6:00 a.m. and 7:00 a.m. This first hour of lane operations is often shrouded in darkness, and coincides with the shift-changing period for the cognizant CHP areas, so that routine enforcement actions are rarely taken at this time.

Exhibit 3.14

MEAN VIOLATION RATE BY TIME OF DAY

MARIN 101



The buffer lane separating the San Bernardino Busway from regular traffic undoubtedly discourages casual violations near the beginning and end of the operating period, as does the four-hour length of the operating period, which extends the end of morning operations and the beginning of evening operations well beyond periods of peak traffic flow. Exhibit 3.15 summarizes the proportion of violations clustered at the fringes of the operating periods for each of the three mainline HOV lanes included in the current study.

In the case of Alameda 580, preferential lane restrictions begin officially on Monday at 6:00 a.m. and are legally in force until Friday at 6:00 p.m. This mode of continuous weekday operations has a distinct impact on the pattern of violations experienced on the freeway. As indicated in Exhibit 3.16, a heavy proportion of violations occur between the hours of 6:00 p.m. and 7:00 p.m. In fact, 45.6% of the violations observed on Alameda 580 during the three-hour evening peak occurred during this last hour. It seems evident that some confusion is generated by the signs themselves, which read:

BUSES AND
CARPOOLS
ONLY
6AM MON
THRU
6PM FRI

Evidently, a large proportion of drivers wrongly interpret this to mean 6AM THRU 6PM, MONDAY THRU FRIDAY. Whether this misinterpretation is deliberate or not, a significant proportion of peak period violations could presumably be eliminated by redesigning either the signs or the operating hours. If the signs were revised to read:

6AM MON
THRU
7PM FRI

violations caused by misinterpretation would at least be pushed beyond the peak commute hours when there is little incentive to violate. Alternatively, the operating hours themselves could be revised to resemble those on Marin 101, where restrictions are in effect <u>only</u> during the peak hours of traffic flow.

<u>General Observations</u>. The pattern of violations within the period of HOV lane operation raises the issue of whether peak period only or all day operation is preferable from an enforcement standpoint. The small number of mainline projects included in the study does not provide a basis for a set of hard and fast rules. San Bernardino and Marin 101 operate only during the peak periods, AM and PM. Alameda 580 operates all day during the weekdays (6:00 AM Monday to 6:00 PM Friday). Only San Bernardino operates on the weekend (peak period hours only). Marin 101, since it lacks any HOV lane separation, could require additional enforcement if the hours of operation were extended. Although enforcement during only the PM peak period was found to reduce the

Exhibit 3.15

PROPORTION OF VIOLATIONS OCCURRING DURING FIFTEEN MINUTES AT BEGINNING AND END OF OBSERVATION PERIOD

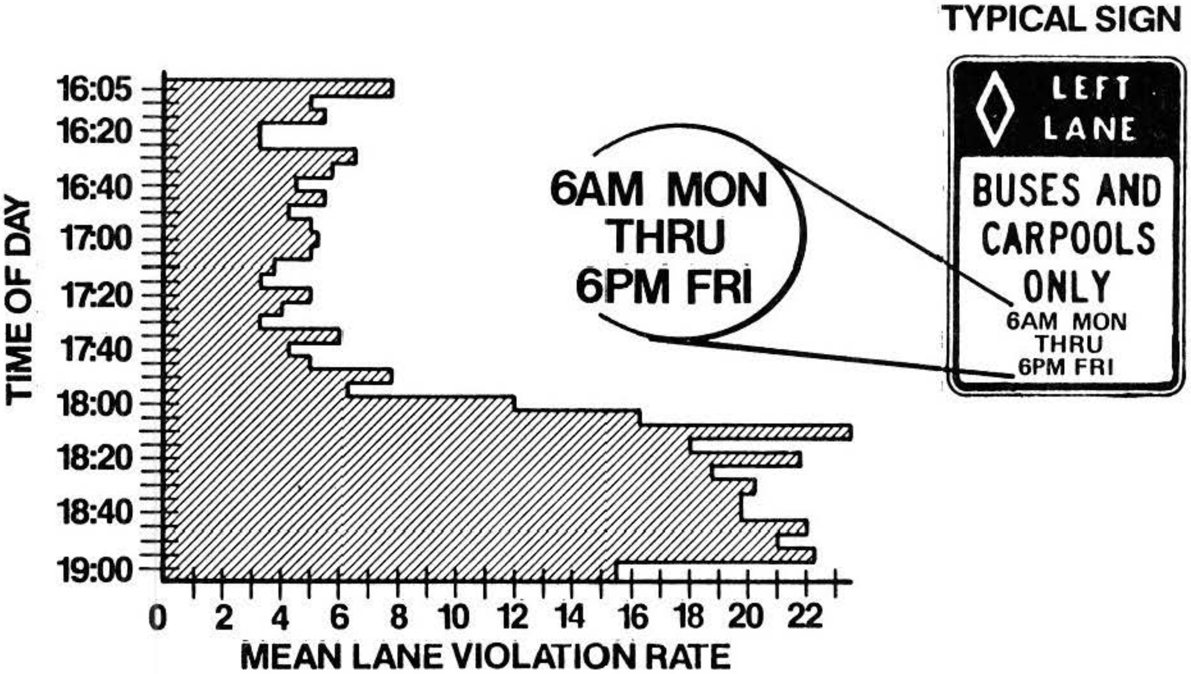
Project	Posted HOV Lanes Operating Hours	% of Violations in First 15 Minutes	% of Violations in Last 15 Minutes
Marin 101	6 to 9 A.M.	4.9	30.0
	4 to 7 P.M.	20.1	14.0
San Bernardino Busway	6 to 10 A.M.	4.7	3.1
	3 to 7 P.M.	1.1	0.8
Alameda 580	6 A.M. Monday to 6 P.M. Friday Operations observed from 6 to 9 A.M. and 4 to 7 P.M.	12.0	5.4*

NOTE: 45.6% of the violations on Alameda 580 during the P.M. peak occurred between 6 P.M. and 7 P.M.

Exhibit 3.16

MEAN VIOLATION RATE BY TIME OF DAY

ALAMEDA 580



AM peak period violation rate, it is not clear that enforcement during one peak period would reduce violation rates during the off-peak. Balancing this, there would be little incentive to violate during the off-peak on any of these projects since traffic volumes on these freeways peak sharply and there is little congestion during the off-peak hours. Nonetheless, some violations would occur, whether through confusion or cussedness. As in the case of ramp bypass lanes, correlations of violations with time savings on mainline HOV lanes show that some violations occur even when little or no time savings are realized. As a practical matter, moreover, it is virtually impossible to enforce occupancy restrictions outside of daylight hours.

All-day operations of the San Bernardino Busway would probably not significantly increase violations during the off-peak in the fully separated section of the busway or in the median lane section. Violators would have little travel time incentive to use the HOV lanes and any additional violators could be contained by routine enforcement. Weekend use of the San Bernardino Busway was allowed in order to simplify signing requirements. Despite moderate Sunday afternoon congestion there appears to be little problem with HOV lane violations. Alameda 580, the only all-day project, requires little enforcement during the off-peak. In summary, the opening of partially or fully separated HOV lanes to all-day operation would probably not greatly increase inforcement requirements and may simplify signing and reduce confusion during the changeover times. At the same time, the additional hours of HOV lane operation would in most cases do little to encourage increased carpooling because of low speed differentials.

3.2.2 Separation Impacts

Although only a few mainline lane projects were observed as part of the study, they represented a wide spectrum of geometric configurations with differing levels of separation between the general traffic lanes and the HOV lanes. The mainline HOV lanes were either fully separated (San Bernardino Busway -- westerly segment), partially separated (Alameda 580 and the easterly segment of the San Bernardino Busway), or concurrent flow (Marin 101). The western segment of the San Bernardino Busway has the highest possible level of separation between general and HOV traffic. The Busway operates much like a "tunnel" with one lane going in each direction and merging limited to the entrance and two exits. The eastern section of the busway has a moderate separation of the median HOV lanes by a thirteen foot common shoulder but crossing is still possible at any time. Alameda 580 is constructed similarly with an eight foot shoulder between the HOV lane and general lanes. Marin 101 has the least physical separation of lanes. The median lane of the freeway functions as an HOV lane without any physical barriers or buffer shoulder. Until recently, the lane was not even painted differently (i.e., no diamond symbols or special lane delineation) because the project was installed before state standards were adopted.

The level of lane separation undoubtedly influences the lane violation rate on mainline HOV lane projects. The fully separated section of the San Bernardino Busway is rarely used by non-carpoolers and the need for enforcement virtually nil. Violators who enter this section of the Busway are essentially "trapped" for its entire length and evasion from enforcement officers is impossible. The median lane section of the Busway has higher violation rates, between 5 and 10% of the users of the lane are violators. Enforcement is fairly simple since the buffer shoulder can be used as a refuge area to pull over violators. Alameda 580 has still higher violation rates, between 20 and 30%. Enforcement of the lanes is not difficult but is not pursued as vigorously as for the San Bernardino Busway. By the close of the study, Marin 101, with the lowest level of separation, had one of the highest levels of violations (27%) and yet was the most vigorously enforced of all the mainline projects. The lack of a refuge area beside the HOV lane makes enforcement difficult and possibly dangerous. Violators are escorted across three general traffic lanes to the freeway shoulders. This method also reduces the visibility of HOV lane enforcement since passing motorists are unsure of what type of citation is being written.

Two projects that were not included in the study also support the hypothesis that greater separation of the lanes help keep violation rates low. The Santa Monica diamond lanes, also in Los Angeles, were non-separated concurrent flow lanes. During its short but controversial life, the freeway experienced violation rates of about 15% and severe safety problems stemming from the lack of lane separation. (Reference 6) The San Bernardino Busway did not experience these problems. In the final evaluation report for the San Bernardino Busway (Reference 15), the local CHP were reported to have felt that the key factor in this difference was the absence of physical barriers on the Santa Monica diamond lanes. Another fully separated HOV lane, on the Shirly Highway in Fairfax County, Virginia, has also proven to be relatively trouble-free. The violation rate ranges around 2.5% and enforcement is minimal.

The benefits of reduced enforcement needs for a fully separated HOV lane must, of course, be balanced against the sometimes prohibitively high costs of construction (see Section 6.2.2). Yet, it is clear that the "low cost" alternative of a totally unseparated median HOV lane is often far from inexpensive in terms of enforcement requirements and safety implications.

3.3 SUMMARY

Several aspects of HOV project design have a critical bearing on enforcement and violation rates. Foremost among these are the need for collaboration between design and enforcement agencies early in the planning process, and the requirement for adequate refuge areas to support field enforcement activities. Early collaboration between design and enforcement agencies will:

- open a channel of communication and promote cooperative relationships;

- ensure that enforcement costs will be reflected in budget projections and alternatives analyses;

- incorporate enforcement requirements in project design; and

- provide advance warning so that field officers can be alerted to special enforcement requirements.

Adequate refuge areas for apprehending and ticketing violators are essential for the safe and efficient enforcement of ramp meter bypass lanes, mainline HOV lanes, and exclusive lanes at toll plazas.

3.3.1 Ramp Meter Bypass Lanes

Impact of Design on Violations. Driver delays on metered ramps are a function of both queue lengths and the designed metering rate. Little correlation was found between the duration of these delays and ramp violation rates. Although violation rates under conditions of routine enforcement increased slightly with the delay in the queue, rising to an average of 19% for delays of two minutes, the violation rate recorded for delays under 20 seconds was a still-formidable 12%. Drivers tended to overestimate the time to be saved by using the ramp bypass lanes, so that even the shortest delays were accompanied by significant violation rates. Short delays were not uncommon on Los Angeles and San Diego ramps, as the majority of the data points recorded by roadside observers reported delays of under 20 seconds.

Although violation rates varied widely and unpredictably with ramp conditions, there was some evidence to suggest that driver's perceptions of delay stemmed not so much from the queue length as from the metering rate. Given the same delay, drivers appeared to be more willing to stay in a long queue which was moving relatively fast than in a short queue which was moving very slowly because of a long red phase in the meter cycle.

Geometric configurations which hide patrol officers from the view of potential violators contributed suprisingly little to the effectiveness of enforcement activities. Special enforcement actions taken from non-visible positions had slightly longer residual impacts than enforcement actions taken in full view of motorists entering the ramp. From the standpoint of reduced violation rates, however, the differences between the results of visible and non-visible ramp enforcement actions were neither striking nor statistically significant. Visible enforcement proved to be nearly as effective as non-visible enforcement, and many officers felt that added visibility increased the safety margin associated with roadside enforcement.

Impact of Violations on Freeway Performance. Less than twenty percent of the drivers using ramp bypass lanes illegally do so through maneuvering which could represent a direct safety hazard to other drivers. By using bypass lanes illegally, however, all violators represent an indirect threat to the long-term time savings, accident relief, and other benefits obtainable through metered ramp control. A sensitivity analysis undertaken on a model of a single roadway, the Santa Monica Freeway, suggested that violations are likely to have a disproportionate impact on these benefits. For the modeled freeway, nearly all of the benefits of meter control were negated by the time ramp violations reached 50%, and violation rates of 20% brought about a disproportionate 42% reduction in passenger time savings.

The relationship of ramp violations to freeway flow is heavily dependent on the characteristics of the individual roadway, the number of ramps provided with bypass lanes, and the metering strategy selected. In most cases, however, the following general design procedures should limit the adverse impacts of ramp violations on freeway flow:

- Designers should treat the possibility of violations explicitly and assume a violation rate of 5% will exist on all ramps provided with HOV bypass lanes. Metering rates should be set to accommodate this level of violations.

- Sensitivity analyses should be undertaken to identify those critical ramps (generally those ramps just upstream from bottlenecks) on which violations are likely to have the most negative impact on freeway flow. On these ramps, designers should either provide no HOV bypass lanes or build a larger safety factor than the 5% level suggested above into the metering rate to offset the adverse impacts of violations.

Refuge Areas. Officers must, at a minimum, be provided with a safe and suitable vantage point and an adequate shoulder area beyond the meter for apprehending and ticketing violators. If possible, the refuge area should be out of the line of sight of potential violators and shielded from the view of passing motorists on the freeway itself.

Meter Placement and Design. Violation statistics in California provide no strong support for or against metering the HOV lane itself. More drivers run the red signal when both lanes are metered since the HOV lane no longer provides a convenient avenue around the metered signal. Enforcement actions are somewhat simpler and safer when both lanes are metered, since occupancy violators are generally traveling slower after stopping to observe the red signal.

Traffic-Responsive Meters. Since traffic-responsive meters can turn green during periods of low freeway usage, the total number of violations experienced with these meters is likely to be lower than the corresponding number for pre-timed meters. There is currently no evidence to suggest whether violation rates during metering periods will differ with traffic-responsive meters. When installing traffic-responsive meters, it is essential that some mechanism be devised to enable officers downstream from the meter to know whether or not the meter is operational.

Left-hand vs. right-hand lanes. The selection of left-hand or right-hand lanes for preferential treatment depends on a number of site-specific factors, including merging conditions, signal position, refuge area location, and ramp access problems. When vehicles may turn left from surface streets onto a ramp, the left lane is preferred for HOV treatment.

Trapping Ramps. Certain ramp designs have the potential for trapping law-abiding drivers against their will in reserved lanes, particularly when left-turns are permitted from a surface street onto a ramp which reserves its left-hand lane for buses and carpools. Violation rates are almost universally higher on these ramps when the right hand lane overflows onto the surface street, so that left-turning vehicles are trapped in the carpool lane. Such "trapping" designs pose special problems for both drivers and enforcing officers and should be avoided if at all possible. Problems are minimized on such ramps, and violation levels respond to enforcement efforts, when overflows are infrequent and relatively few autos make the turning movement which springs the trap. When most of the vehicles entering a ramp make the turning movement that can potentially leave them trapped in the carpool lane, however violation rates are not likely to respond to enforcement. In such cases, carpool restrictions should be avoided and all lanes should be opened to general traffic.

Special Striping. Sample ramps with bold stripes painted to form a continuous diamond pattern had significantly lower violation rates than ramps with conventional striping during the first six months of bypass lane operation. As time went on, however, the deterrent effect of special striping apparently diminished, and after nearly two years of operation, comparison tests showed no significant difference between violation rates on routinely enforced ramps with and without special striping. The first wave of special enforcement caused violation rates to drop appreciably on ramps with and without special striping, and the presence or absence of special striping apparently had little impact on violation rates during and after special enforcement activities.

Use of Delineators. Candlestick delineators separating the HOV lane and general traffic lane had no measurable effect on violations, and the short life span of the delineators made their use expensive as well as ineffective.

3.3.2 Mainline HOV Lanes

Hours of Operation. On Marin 101, violations tend to cluster on the fringes of the morning and evening operating hours, with a high proportion occuring just after restrictions come into play at 6:00 a.m. and again at 4:00 p.m., and just before restrictions are removed at 9:00 a.m. and 7:00 p.m. In the case of Alameda 580, preferential lane restrictions begin officially on Monday at 6:00 a.m. and are legally in force until Friday at 6:00 p.m. However, an unusually high proportion of violations occur between 6:00 p.m. and 7:00 p.m. every weekday, suggesting that a large number of drivers wrongly interpret the operating hours to be 6:00 a.m. to 6:00 p.m., Monday through Friday. In this case, a significant proportion of peak period violations could be eliminated by redesigning either the signs or the operating hours.

On the separated right-of-way of the San Bernardino Busway, violations during the evening peak coincide with peak traffic volumes, while violations during the morning peak are concentrated during the first hour of lane operations, when darkness and CHP shift changes combine to create a lull in enforcement activities.

The limited number of projects examined provides little insight into the question of whether all-day operation is preferable to peak period operation for mainline HOV lanes. The opening of such lanes to all day operations is not likely to increase either violation level or enforcement requirements appreciably, and may simplify signing problems and reduce confusion during the changeover times. At the same time, it is impossible to enforce occupancy restrictions after dark, and the additional hours of HOV lane operation at times when there is no time advantage to be gained from using the lane are not likely to encourage many additional carpools.

Refuge Area. Both the San Bernardino and Alameda 580 have adequate refuge areas either on the buffer strips separating the preferential lanes from general traffic or on the median. The absence of such areas in Marin highlights the need for suitable refuge areas.

On Marin 101, the lack of buffers separating the carpool lanes from general traffic, coupled with the narrowness of the lanes themselves and the absence of a median made it necessary for officers to escort violators across heavy traffic to issue citations on the shoulder of the roadway. Patrol cars had particular difficulty accomplishing the maneuvers needed to pursue and apprehend violators under these circumstances, so that motorcycle patrols had to be used for special enforcement. In this case, then, certain project design features made enforcement difficult and required the use of special officers. Surveys showed, moreover, that the need to issue tickets on the shoulder of the roadway at a location well removed from the preferential lane left many drivers unaware that the lane restrictions were actually being enforced (see Section 5.1.2).

Lane Separation. By the close of the study, it appeared that the degree of separation between general traffic lanes and the preferential lanes had a measurable impact on violation rates. Lane violation rates were lowest (3% to 4%) on the lightly-enforced western section of the San Bernardino Busway where a physical-barrier made lane switching impossible, and considerably higher (27%) on heavily-enforced Marin 101, where there was no separation whatever between preferential and general lanes. Violation rates were also low (7%) on the buffer-separated portion of the San Bernardino Busway. Violation rates were highest (36%) on the lightly-enforced, buffer-separated lanes of the controversial Alameda 580 project.

4. SAFETY IMPLICATIONS

This Chapter addresses the positive and negative impacts of HOV lanes on freeway safety. Accident rates are compared before and after the introduction of each ramp metering project, ramp bypass lane, and mainline HOV lane considered in the study. Historical accident rates for appropriate times of day are traced over a period of years prior to the implementation of each project to identify existing trends and determine the variability of the accident sample. These "before" statistics are compared with the year-by-year records of accidents occurring over the life of the project. When a project metamorphasis includes several distinct stages, as in the case of a ramp that was originally unmetered, then metered, and finally metered with an HOV bypass lane, accident levels during successive stages are isolated and compared with each other. Accident levels along the freeway segments under the control of metered ramps are tabulated along with accident levels on the ramps themselves. Accident rates on projects with different engineering features are compared, the unsafe maneuvers of HOV lane violators are catalogued, and, where possible, accident rates are correlated and compared with violation rates.

4.1 UNSAFE MANEUVERS BY VIOLATORS

One reason that the CHP has in the past accorded relatively low priority to HOV lane enforcement is that HOV lane violators generally pose no immediate threat to the safety of other freeway drivers. So long as excess capacity exists in a mainline HOV lane, the non-carpoolers who enter and leave that lane safely may actually reduce congestion in the general traffic lanes and could conceivably contribute to safer freeway performance. The violator using a meter bypass illegally typically does not represent a direct safety hazard, although such a violation, if copied by enough drivers, can negate the impact of the meter system and any long-term safety benefits of controlled freeway flow (see Section 6.1.3). However, certain actions by HOV lane violators can threaten the immediate safety of other drivers. Violators making unsafe maneuvers include:

- The Weaving Violator who enters a separated HOV lane illegally and unsafely.
- The Peeking Ducker who darts suddenly into the carpool bypass lane from the adjacent queue (see Reference 3).
- The Turning Wormer who stops suddenly in the carpool bypass lane and attempts to worm his way into the adjacent queue.

- The Unexpected Stopper who stops unnecessarily at the head of an unmetered carpool lane to observe the meter in the adjacent lane.

4.1.1 Weaving Violators

On the San Bernardino Busway, some drivers cross the buffer lane illegally to enter or leave the reserved lane at points other than those provided for access and egress. This movement generally requires movement from a slow-moving to a fast-moving stream of traffic (or vice versa) and is both dangerous and illegal for carpoolers and non-carpoolers alike. Weaving Violations on the San Bernardino Busway were counted by two observers standing at a pet overcrossing near what has historically been the location of the highest weaving violations. With one observer looking east and the other looking west, they covered about 1-1/4 miles of the busway. The following results were recorded before, during, and after the first wave of special CHP enforcement.

Period	Time	Into Busway	Out of Busway	Total	Average
Before Enforcement	AM	9	7	16	19.0
" "	PM	14	8	22	
During Enforcement	AM	5	8	13	14.4
" "	PM	11	6	17	
After Enforcement	AM	3	4	7	10.5
" "	PM	8	6	14	

Thus the special enforcement activity directed against illegal users of the bus/carpool lane had the effect of lowering weaving violations as well. (More information regarding the impact of the special enforcement activity on occupancy violations and the general flow of freeway has been presented in Section 2.2.4). Weaving violations were actually lower after special enforcement activities had ceased than during the period when CHP officers were present. Several factors contributed to this continued decline in weaving violations:

1. Traffic disruption and congestion related to the enforcement activities themselves appeared to increase violation rates somewhat during the enforcement period.

2. The initial post-enforcement period coincided with the onset of summer, which reduced freeway congestion slightly and, with it, the incentive to violate.

4.1.2 Peeking Duckers

Observations of violations on queue-dependent ramps have provided revealing glimpses of motorist behavior. On ramps that had received recent CHP attention, when the queue in the metered lane was long enough to shield enforcement activity from entering motorists, some experienced drivers would join the metered queue just long enough to determine whether an officer was present beyond the meter. While in the queue, they would peek out periodically to check for the presence of an officer, and eventually duck into the carpool lane to become violators if the coast was clear. The maneuvering of these "peeking duckers" can present a hazard to oncoming drivers in the carpool lane. They also frustrate analytic attempts to correlate violations with queue lengths and wait times. As part of the current study, CALTRANS field units were instructed to tabulate peeking duckers separately, so that the extent of this potential hazard could be assessed and their presence could be taken into account when making statistical comparisons of violations and queue lengths.

Exhibit 4.1 summarizes the relative proportion of peeking duckers among bypass lane violators before, during, and after the first wave of special enforcement activities. The exhibit shows that the relative numbers of peeking duckers edging into the bypass lanes increases significantly during and after special enforcement actions. As might be expected, the presence of CHP officers made potential violators more aware of enforcing activities.

4.1.3 Turning Wormers

The mirror image of the peeking ducker is the single driver who uses the carpool lane to pass a number of autos waiting in the metered lane, realizes his error (or spies a waiting CHP officer), stops suddenly, and attempts to turn and worm his way into the meter queue in midstream. The sudden stops and jockeying of these "turning wormers" also present a hazard to oncoming carpoolers, and their presence is also noted by field observors. A high incidence of turning wormers (see Exhibit 4.2) may also indicate poor signing on a particular ramp or an entry problem in which drivers are trapped in the carpool lane.

As in the case of peeking duckers, Exhibit 4.2 shows that the incidence of turning wormers increases with enforcement acitivity. The percentage of turning wormers among ramp violators on a sample of 39 Los Angeles ramp bypass lanes rose from 3.2% before special enforcement to 10.5% following the first wave of enforcement. As would be expected, there is a significantly higher percentage of turning wormers on ramps where enforcement is either not visible or queue-dependent than on ramps where enforcement is immediately visible to all drivers entering the ramp. On ramps where enforcement is visible, potential violators are presumably able to evaluate the enforcement situation more accurately before they violate. They therefore make fewer mistakes and find less need to become "Turning Wormers" than their counterparts on ramps where enforcement is not visible at all points along the length of the ramp.

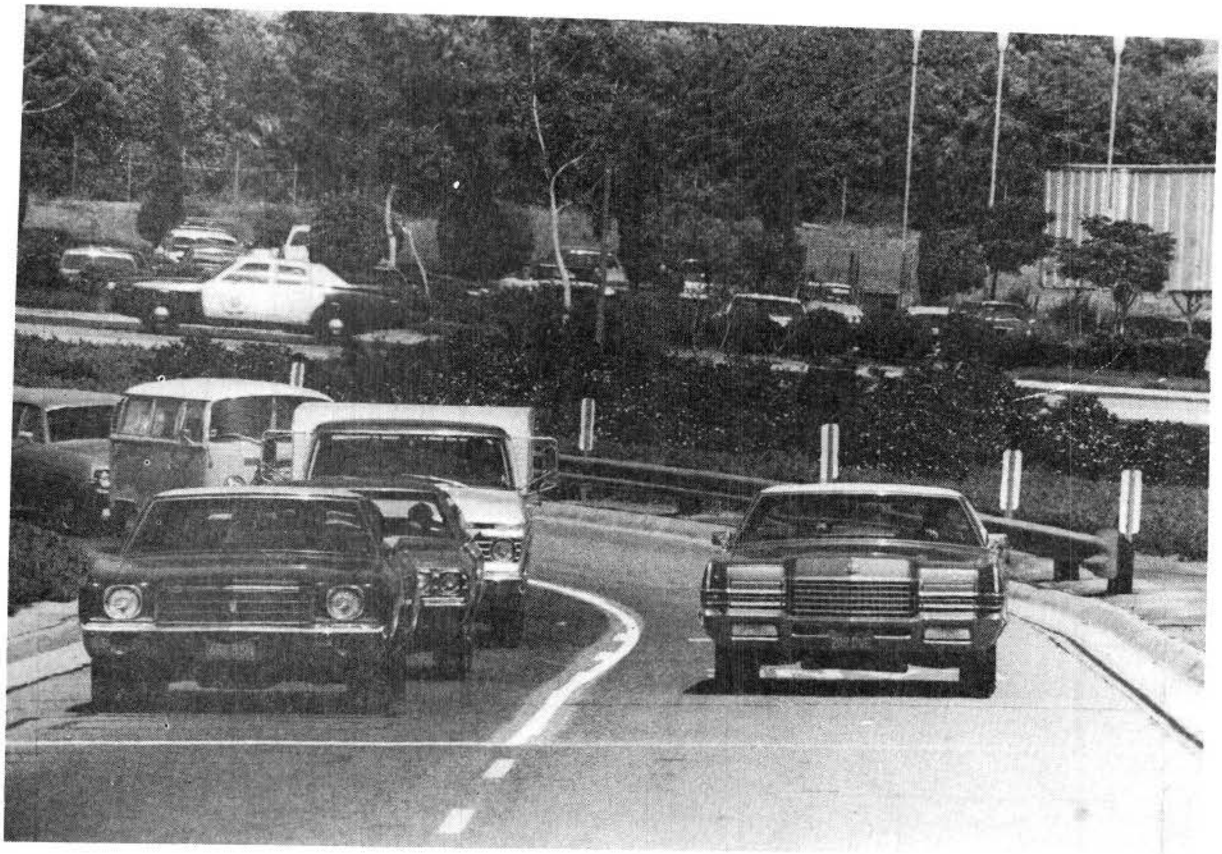


Exhibit 4.1

PEEKING DUCKERS

AS A PERCENTAGE OF ALL VIOLATORS

Enforcement Visibility	Enforcement Phase		
	Before First Wave	During First Wave	After First Wave
Visible	7.1%	24.0%	11.8%
Queue-Dependent	6.6%	8.8%	5.4%
Not Visible	4.5%	7.8%	12.9%
All Ramps	6.0%	11.8%	10.0%

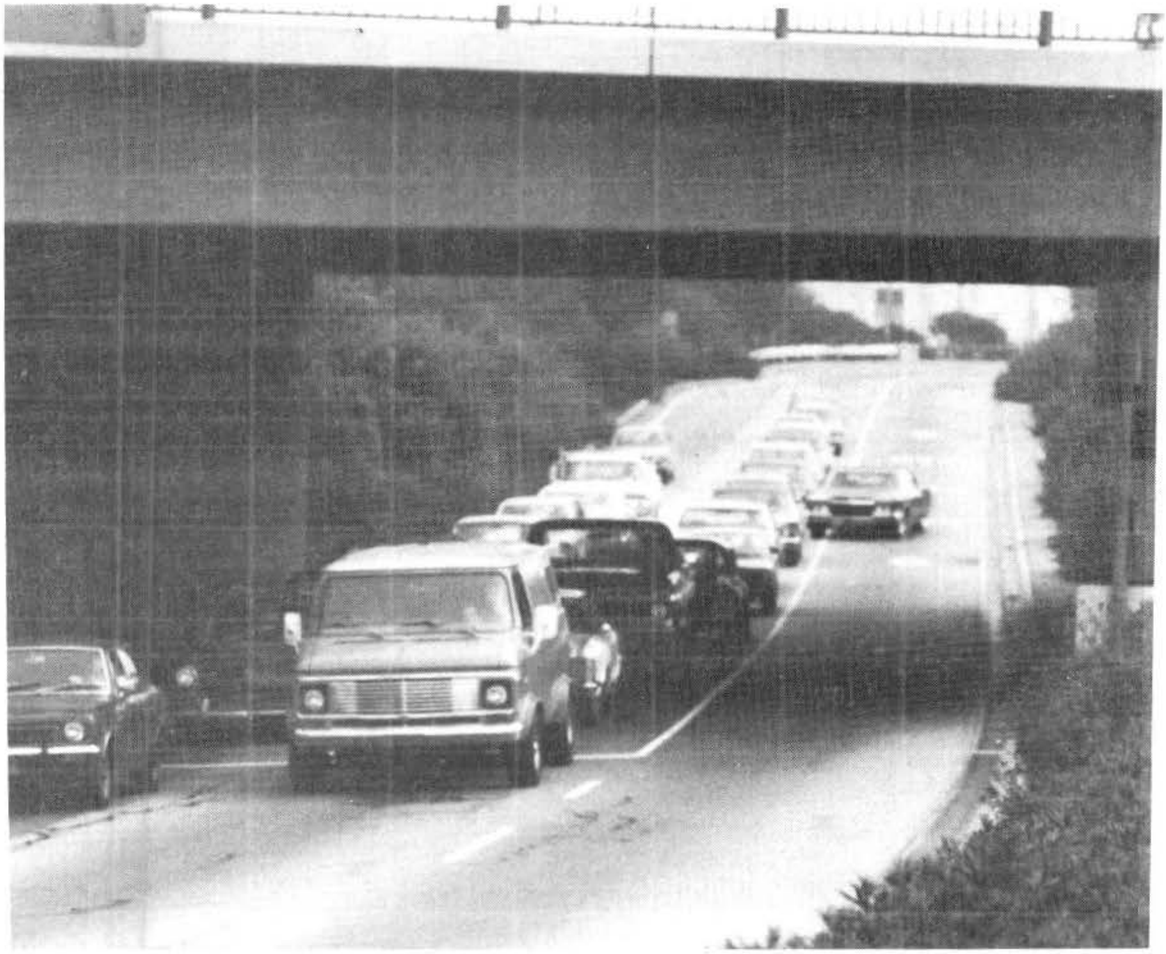


Exhibit 4.2

TURNING WORMERS

AS A PERCENTAGE OF ALL VIOLATORS

	Enforcement Phase		
Enforcement Visibility	**Before First Wave**	**During First Wave**	**After First Wave**
Visible	2.9%	8.8%	5.2%
Queue-Dependent	3.4%	8.5%	11.5%
Not Visible	2.9%	7.6%	14.1%
All Ramps	3.2%	8.2%	10.5%

4.1.4 Unexpected Stops in the HOV Bypass Lane

One potential problem with the unmetered ramp bypass lanes in Los Angeles is that some drivers in the bypass lane stop when they shouldn't to wait for the signal controlling flow in the metered lane. Examination of time-lapse photographs of ramp bypass lanes taken by CALTRANS on six sample ramps showed that an average of 4.3% of all drivers using the carpool lane stopped unexpectedly to wait for the red light in the metered lane. All but one of the drivers observed stopping in this fashion were using the bypass lane illegally. Whereas 35% of the drivers in the bypass lanes on the days studied had only one occupant, these violators accounted for 97% of the unexpected stops in that lane. In this case, at least, the violator represents an immediate safety hazard as well as a potential subversion of the meter system.

4.2 ACCIDENT ANALYSIS: RAMP METERING AND BYPASS LANES

In the case of ramp metering, and ramp meter bypass lanes, the improved freeway flow resulting from controlled ramps can be expected to reduce accident rates on metered freeways. At the same time, the increased queueing and maneuvering on the ramps themselves may cause accident levels to increase on access ramps. Because of the natural fluctuation in accident rates, any attempt to investigate the impact of metering on safety must necessarily cover long time periods and deal in large sample sizes. In designing a meaningful sample for Los Angeles, twenty-two metered freeway segments covering 146.7 directional miles were analyzed. This sample included 110 metered ramps with bypass lanes and 111 metered ramps without bypass lanes.

Since meters operate only during the peak commute hours, only those accidents occurring between 6:30-8:30 AM and 4:00-6:00 PM were considered in the analysis. In addition, to control for the change in demand and speed levels on the sample segments of freeways over the years, peak hour volumes recorded by freeway sensors were used to determine annual travel along the sample segments and translate accident data into accidents per million vehicle miles.

Since accidents on any freeway segment fluctuate widely from year to year, a base period of at least three years prior to the introduction of ramp metering was established for comparison purposes. To accommodate this base period, it was necessary to assemble data from as far back as 1970 on several freeways.[1]

To investigate the safety implications of ramp metering and ramp bypass lanes, the following comparisons were made:

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[1] Prior to 1972, computer accident records did not distinguish between ramp accidents and freeway accidents. Accordingly, comparisons involving separate analyses of ramp accidents rely on post-1972 data.

1. Freeway accident rates were compared before and after the introduction of ramp metering;

2. Accident rates on metered ramps were compared before and after the implementation of ramp metering;

3. Accident rates on ramps with and without bypass lanes were compared before and after metering;

4. For those ramps on which bypass lanes were installed after ramp meters were operational, accident rates were compared for three time periods:

   - before metering

   - after metering but before HOV bypass lane

   - after HOV bypass lane

5. Total system accident rates (freeway plus ramps) were compared before and after the introduction of ramp metering.

4.2.1 Freeway Accidents

Exhibit 4.3 compares accidents occurring on the sample segments of freeways before and after ramp metering. In general, freeway accidents drop slightly after ramp metering. Accident rates before metering range from a low of .31 accidents/MVM on the sample segment of W/B Riverside Freeway (AM) to a high of 2.71 accidents/MVM on the sample segment of N/B Golden State Freeway (PM). After metering was introduced, accident rates vary from .18 accidents/MVM (W/B Riverside Freeway, AM) to 2.23 accidents/MVM (S/B San Diego Freeway before metering, PM). The overall accident rate drops 10.4%, from 1.15 accidents/MVM to 1.03 accidents/MVM after metering. The tabulated results indicate that accident rates vary not only between freeways but also between adjacent segments on the same freeway.

To investigate the existence of any accident trends that might be related to ramp control, accidents on sample segments were aggregated over each of the five years before and after metering. Exhibit 4.4 displays the two 5-year trend lines representing the before and after condition. The points represent average accident levels on the sample freeway segments during the five years before and after metering. Actual accident levels on individual segments varied widely about these average values, leading to low correlation coefficients and a lack of statistical significance. Although the freeway accident trend for the five years following metering was downward, the yearly rates recorded over this five year period did not differ significantly from the yearly rates recorded prior to metering (at the .05 level of significance).

Exhibit 4.3

PEAK PERIOD ACCIDENT RATES BEFORE AND AFTER RAMP METERING ON SAMPLE FREEWAY SEGMENTS IN LOS ANGELES

(excluding ramp accidents)

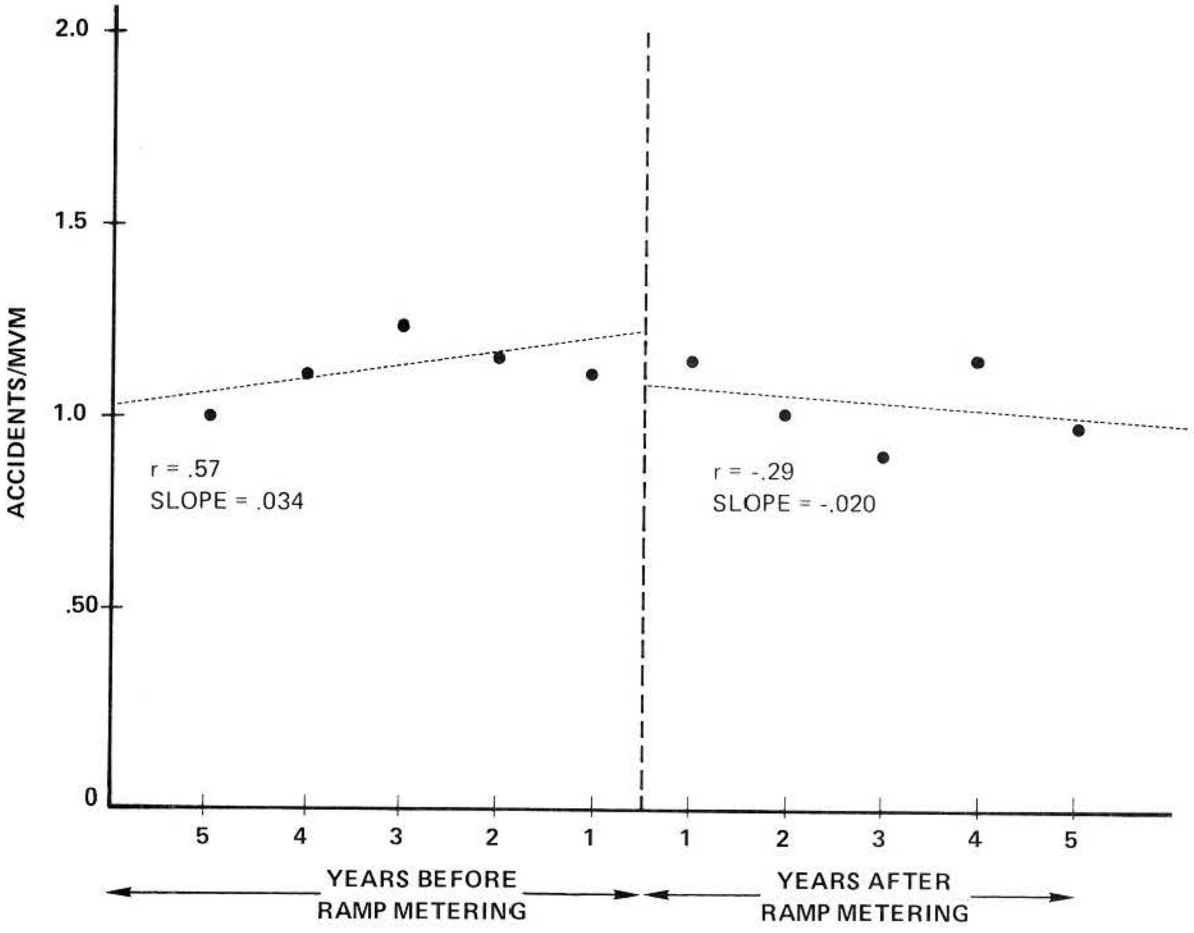
Freeway (Direction, Post Mile, Peak Period)	Before Ramp Metering			After Ramp Metering			% Change in Accident Rates
	Time Period	No. Accidents	Accidents/ MVM	Time Period	No. Accidents	Accidents/ MVM	
LA5: Santa Ana Fwy & Golden State Fwy							
SB, 16.485-27.72, AM	72-6/75	225	1.82	7/75-1980	260	1.22	↓ 33.0%
SB, 29.642-34.63, AM	73-8/77	58	1.00	9/77-1980	59	1.27	↑ 27.0%
NB, 20.025-25.903, PM	70-6/72	137	2.71	7/72-1980	170	0.96	↓ 64.6%
OR5: Santa Ana Fwy							
SB, 34.76-41.79, PM	73-10/77	75	0.78	11/77-1980	42	0.67	↓ 14.1%
LA7: Long Beach Fwy							
SB, 14.851-19.800, PM	75-1978	47	0.71	1979-1980	30	0.91	↑ 28.2%
NB, 15.143-19.890, AM	75-1978	50	0.79	1979-1980	29	0.91	↑ 15.2%
LA10: Santa Monica Fwy							
EB, 7.218-13.969, AM	72-5/75	169	1.77	6/75-1980*	125	0.91	↓ 48.6%
WB, 9.253-12.66, PM	72-7/74	95	2.40	8/74-1980*	135	1.62	↓ 32.5%
LA11: Harbor Fwy							
NB, 8.101-19.170, AM	72-7/76	219	1.21	8/76-1980	182	1.05	↓ 13.2%
LA91: Artesia Fwy							
EB, R14.68-R17.40, PM	75-3/79	39	0.87	4/79-1980	15	0.71	↓ 18.4%
WB, R11.788-R19.38, AM	75-3/79	193	1.59	4/79-1980	90	1.58	↓ 0.6%
OR91: Riverside Fwy							
EB, R0.741-R2.60, PM	75-2/79	16	0.75	3/79-1980	4	0.41	↓ 45.3%
WB, R0.430-R2.65, AM	75-3/79	8	0.31	4/79-1980	2	0.18	↓ 41.9%
LA101: Ventura Fwy							
SB, 12.719-23.18, AM	75-9/79	287	1.45	10/79-1980	58	1.04	↓ 28.3%
LA170: Hollywood Fwy							
SB, R15.262-R17.144, AM	75-9/79	26	1.08	10/79-1980	9	1.26	↑ 16.7%
LA405: San Diego Fwy							
SB, 0.884-4.94, PM	70-3/72	61	1.86	4/72-1980	311	2.23	↑ 19.9%
NB, 3.24-7.24, AM	70-4/72	40	1.13	5/72-1980	89	0.64	↓ 43.4%
NB, 17.566-20.18, AM	70-1972	45	1.65	1973-1980	39	0.49	↓ 70.3%
NB, 30.166-38.94, PM	72-1976	227	1.43	1977-1980†	229	1.45	↑ 1.4%
SB, 28.892-42.26, AM	73-6/78	298	1.10	7/78-1980	147	0.96	↓ 12.7%
LA605: San Gabriel River Fwy							
NB, R1.553-R13.70, AM	72-2/78	101	0.38	3/78-1980	41	0.29	↓ 23.7%
SB, R1.597-R16.55, PM	72-1977	259	0.82	1978-1980	123	0.64	↓ 22.0%
Overall Total		2,675	1.15		2,189	1.03	↓ 10.4%

*1976 data were excluded because of the unusually high accident rates during the operation of Diamond Lanes

†One lane (1.4 miles) was added to this section in January 1977

Exhibit 4.4

FREEWAY ACCIDENT TRENDS BEFORE AND AFTER RAMP METERING IN LOS ANGELES



4.2.2 Accidents on Metered Ramps

Los Angeles. As classified in the CHP accident reporting system, ramp accidents include all accidents occurring at the junction of the ramp and the freeway, on the ramp itself, at the ramp entrance, and in the immediate vicinity of the entrance on the surface street. Since accidents occurring at the ramp entry or on the surface street at the intersection created by the ramp entrance are likely to reflect traffic conditions on the ramp itself (as when the metered lane overflows onto the surface street or when left-turn problems exist at the ramp entrance), all four classes of ramp accidents were included in this analysis.

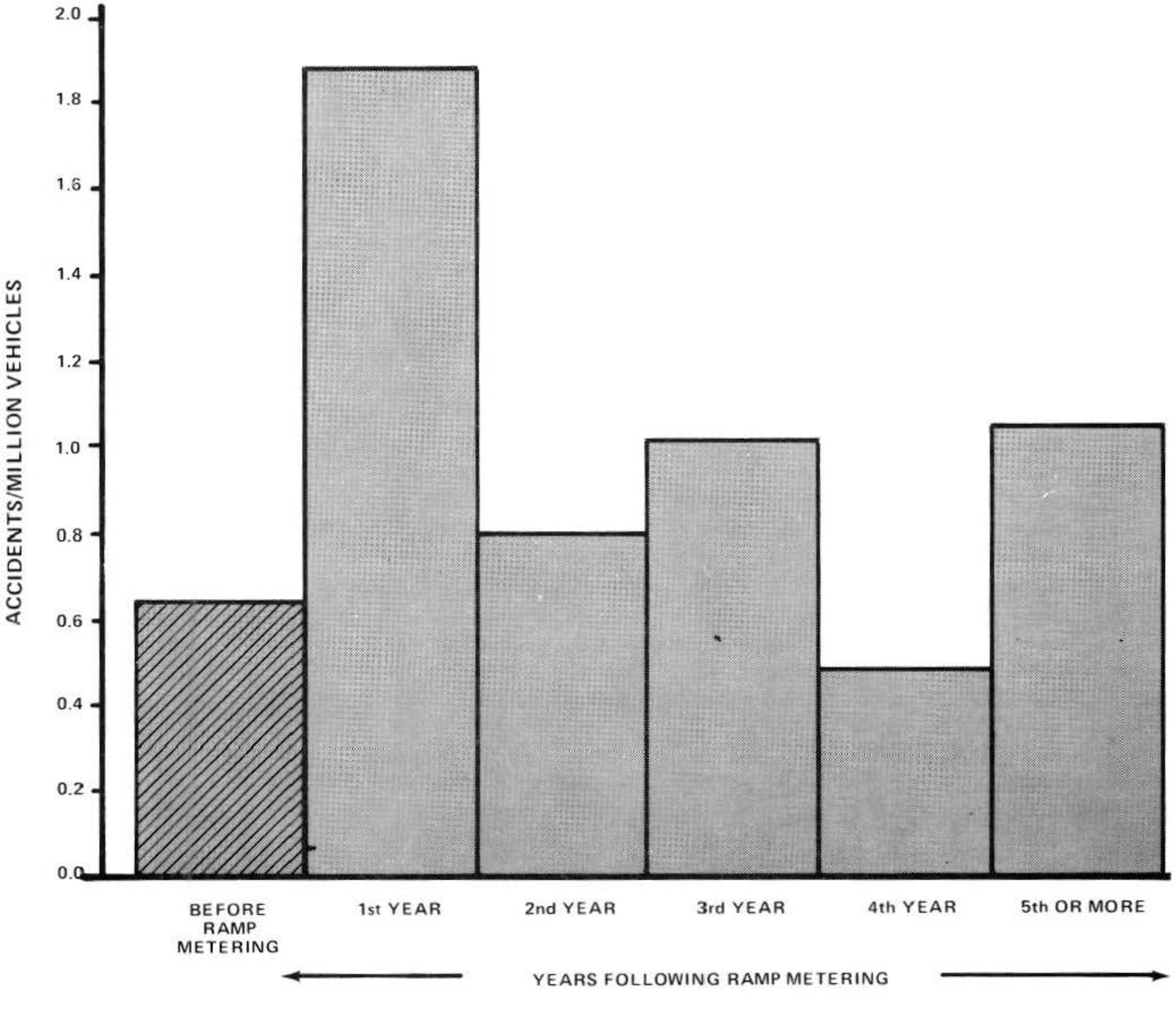
In the past, relatively few studies have addressed the topic of accidents on ramps under meter control. The few studies that have done so have either used a small sample or looked at a limited time period (typically one year before and one year after the treatment condition). Those studies that have considered a longer time period have used accidents per ramp per year as the basic unit of comparison, implicitly assuming the levels of demand and capacity of all ramps are equal. Since ramps differ markedly from each other in demand levels and other characteristics, and since demand levels change both with time and ramp metering rates, a measurement reflecting the demand levels on each ramp will give a more accurate picture of ramp safety. To make the analysis more meaningful, therefore, an accident rate based on the volume of traffic on each ramp is used. Peak hour ramp volumes before and after ramp metering were provided by CALTRANS. Where direct volume counts were unavailable, ramp volumes were estimated on the basis of Average Daily Traffic (ADT) data recorded on the freeway itself.

To determine the impacts of metering on ramp safety, accident rates before and after ramp metering were tabulated for a sample of 111 metered ramps with no bypass lanes. Overall results indicate that accidents on these ramps almost doubled after ramp metering, rising from 0.64 accidents/million vehicles to 1.16 accidents/million vehicles. These overall statistics mask some significant accident trends, which are shown in Exhibit 4.5. This exhibit presents a year-by-year breakdown of ramp accident levels after the introduction of metering. The charted results reveal that ramp accidents increased dramatically (nearly tripling) the first year after metering to 1.89 accidents/million vehicles. As drivers became accustomed to ramp metering, accident rates dropped considerably during subsequent years, to approach pre-metering levels at an average of 0.88 accidents/million vehicles.

Exhibit 4.5

ACCIDENT RATES ON METERED ON-RAMPS WITHOUT BYPASS LANES BEFORE AND AFTER METERING

(A Sample of 111 Ramps in Los Angeles)



4.2.3 Accidents on Metered Ramps with Bypass Lanes

Concurrent Installation of Metering and Bypass Lanes. To determine whether metered ramps with bypasses had different accident histories than metered ramps without bypasses, a sample of 87 ramps with bypass lanes was studied in detail. On each of these ramps, the bypass lane was implemented at the same time that metering was installed. Overall accidents on this sample of ramps were low before ramp metering bypass (RMB) lanes were installed, averaging .46 accidents/million vehicles. After RMB, accident rates almost tripled to 1.33 accidents/million vehicles. Exhibit 4.6 charts accident levels on a yearly basis after RMB lanes were installed. Unlike the descending trend observed in the sample of meter-only ramps, accident rates remain high after the first year of operation on ramps with bypass lanes. Ramp accidents nearly tripled the first year after RMB, rising to 1.26 accidents/million vehicles, and they failed to drop during the subsequent years, averaging 1.38 accidents/million vehicles.

Exhibit 4.7 summarizes the overall accident rates on metered ramps with and without bypass lanes. Accident levels increased by roughly the same amount in both samples during the first year following the introduction of ramp metering. In subsequent years, however, accident levels declined on metered ramps without bypasses, while accident rates actually increased slightly on ramps with bypasses.

Exhibit 4.7 also breaks down accident rates on ramps with bypasses according to the violation rates measured on the sample ramps prior to special enforcement. Accident records are aggregated in groups of high, medium and low violation ramps. During the first year following the implementation of metering and bypass lanes, accident levels appear to be roughly the same on ramps in each of these violation categories. During subsequent years, however, accident rates drop somewhat on ramps with medium and low violation rates, while increasing dramatically on ramps with high violation rates. This suggests that the failure of accident levels to drop after the first year of metering on ramps with bypass lanes may be correlated with violation rates. A plausible explanation for the persistence of high accident levels following the introduction of ramp bypass lanes may be found in the unsafe maneuvers of certain violators (the peeking duckers, turning wormers, and unexpected stoppers described in Section 4.1) who attempt to avoid delays and apprehension simultaneously. The fact that ramps subsequently falling in the "high violation" category had slightly higher accident levels even before ramp metering was introduced, tends to add further support to the hypothesis that drivers using ramps with high violation rates have worse overall driving records than drivers on other ramps (see Section 5.2).

Staged Installation of Metering and Bypass Lanes. While meters and bypass lanes were implemented concurrently on most Los Angeles ramps, there is a small sample of ramps where the bypass lanes were added after the meters had already been operating. It is therefore possible to assess the effect of adding a bypass lane to an already metered ramp. The following table presents the accident rates for the

Exhibit 4.6

ACCIDENT RATES ON RAMP METER BYPASSES BEFORE AND AFTER RAMP METERING

(A Sample of 87 Ramps in Los Angeles)

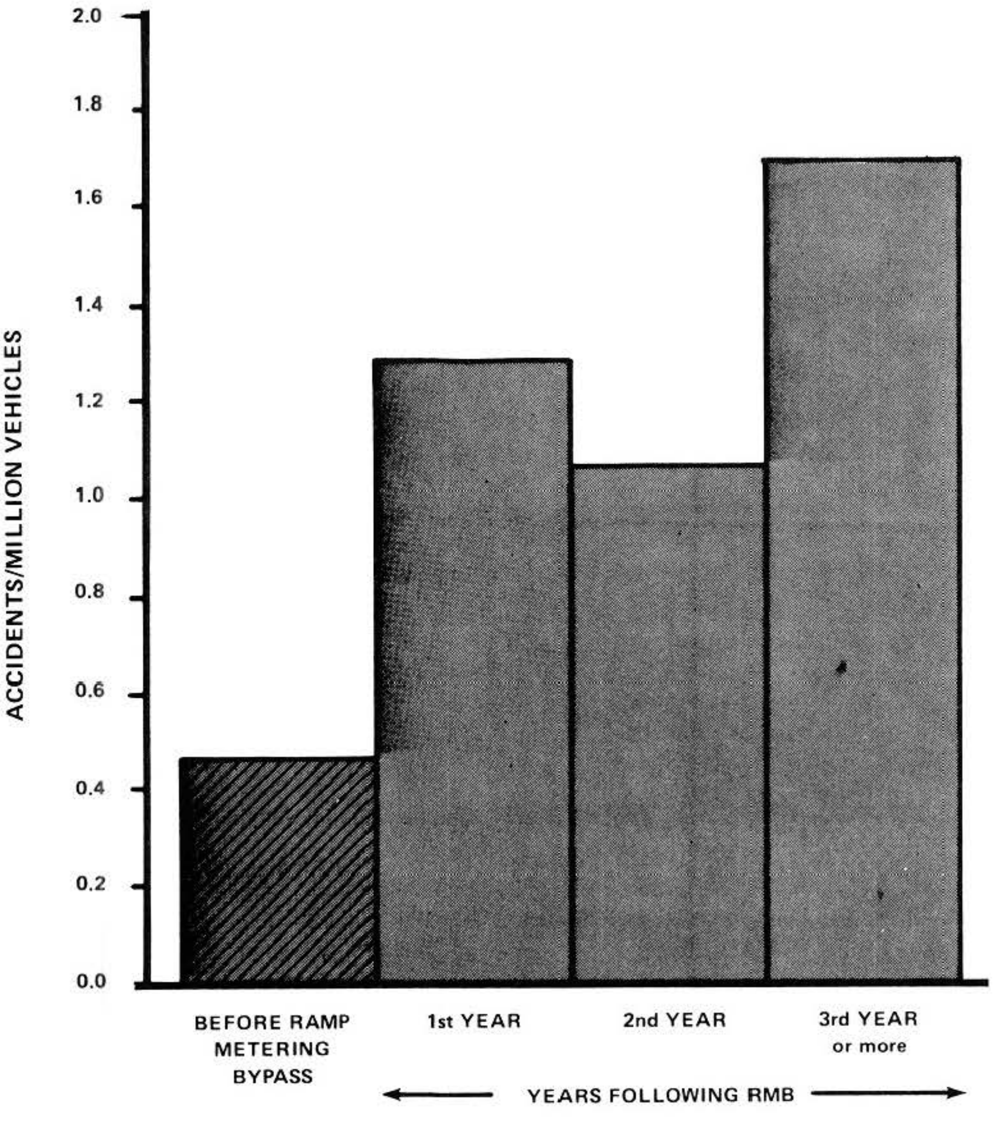


Exhibit 4.7

ACCIDENT RATES ON METERED RAMPS
(With and Without Bypass Lanes)

Los Angeles Ramps	Before Metering	After Metering			
		First Year		Subsequent Years	
	ACC/MV	ACC/MV	% Change from "Before"	ACC/MV	% Change from "Before"
Meter Only (111 ramps)	0.64	1.88	↑194%	0.88	↑ 37.5%
Concurrent Metering and Bypass (87 ramps)	0.46	1.26	↑174%	1.69	↑ 167%
Bypass Ramps by Violation History*					
• Low Violation Ramps (n = 20)	0.36	1.48	↑311%	0.92	↑ 156%
• Medium Violation Ramps (n = 34)	0.41	1.22	↑198%	0.83	↑ 102%
• High Violation Ramps (n = 19)	0.74	1.40	↑ 89%	2.41	↑ 226%
• Unclassified (n = 14)	0.44	0.87	↑ 98%	0.58	↑ 32%

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*Violation rates ranked prior to special enforcement three conditions: Before Metering; Meter-only Operations; and Bypass Lane Operation.

ACCIDENT RATES ON RAMPS
WITH BYPASS LANES INSTALLED AFTER RAMP METERING

	Before Metering		After Metering		After Metering & Bypass Lanes	
RAMP VIOLATION RATE	Accidents	Acc/MV	Accidents	Acc/MV	Accidents	Acc/MV
Low (8 ramps)	0	0	12	1.47	2	0.48
Medium (10 ramps)	0	0	13	1.34	14	1.51
High (5 ramps)	2	.47	2	0.52	10	3.31
TOTAL (23 ramps)	2	.25	27	1.30	26	1.58

Before metering, ramp accidents were low, averaging .25 accidents/million vehicles. After metering, ramp accidents jumped to 1.30 accidents/million vehicles and after the introduction of bypass lanes, accident levels rose 21.5% to 1.58 accidents/million vehicles. It appears, therefore, that the presence of a bypass lane in addition to ramp meters may lead to higher accident levels. This result is consistent with the increases observed on the earlier sample of ramps in which bypasses were introduced at the same time as ramp metering. As in the case of the earlier sample, accident levels appear to be higher on ramps where violation rates are higher.

4.2.4 Total System Accidents

Ramp accidents were rare events prior to metering, occuring once every eight years on a typical Los Angeles ramp. Even after the increases associated with metering and bypass lanes, ramp accidents remained relatively infrequent, occuring once every three years on a metered ramp with a bypass and once every four years on a metered ramp without a bypass. This increase was not sufficient to offset the decline in freeway accidents accompanying the introduction of ramp metering.

When ramp accidents are added to accidents occuring on the freeway itself, total system accidents on the same freeway segments discussed earlier stood at 1.34 accidents/MVM before metering. After ramp metering, total system accidents drop only 4.5% to 1.28 accidents/MVM, as compared with a 10.4% drop in accident rates on the freeway alone (see Exhibit 4.8). Thus, the decrease in freeway accidents attributed to the control of traffic by metering is not entirely offset by the accompanying increase in ramp accidents. Before ramp metering, ramp accidents made up close to 16% of total system accidents, while after metering, they accounted for almost a quarter (23.6%) of all accidents on the freeway network during peak commute hours.

Exhibit 4.8

PEAK PERIOD ACCIDENT RATES BEFORE AND AFTER RAMP METERING ON SAMPLE FREEWAY SEGMENTS IN LOS ANGELES

Total System Accidents: Freeways and Ramps

Freeway (Direction, Post Mile, Peak Period)	Before Ramp Metering			After Ramp Metering			% Change in Accident Rates
	Time Period	No. Accidents	Accidents/ MVM	Time Period	No. Accidents	Accidents/ MVM	
LA 5							
SB, 16.485-27.72, AM	72-6/75	264	2.15	7/75-80	339	1.60	↓ 25.6%
SB, 29.642-34.63, AM	73-8/77	70	1.20	9/77-80	72	1.55	↑ 29.2%
NB, 20.025-25.903, PM	70-6/72	151	2.99	7/72-80	212	1.20	↓ 59.9%
OR 5							
SB, 34.76-41.79, PM	73-10/77	88	0.91	11/77-80	59	0.95	↑ 4.4%
LA 7							
SB, 14.851-19.800, PM	75-1978	64	0.97	1979-80	39	1.18	↑ 21.6%
NB, 15.143-19.890, AM	75-1978	61	0.96	1979-80	37	1.16	↑ 20.8%
LA 10							
EB, 7.218-13.969, AM	72-5/75	206	2.16	6/75-80*	165	1.20	↓ 44.4%
WB, 9.253-12.66, PM	72-7/74	109	2.76	8/74-80*	165	1.99	↓ 27.9%
LA 11							
NB, 8.101-19.170, AM	72-7/76	246	1.36	8/76-80	224	1.29	↓ 5.1%
LA 91							
EB, R14.68-R17.40, PM	75-3/79	45	1.01	4/79-80	17	0.81	↓ 19.8%
WB, R11.788-R19.38, AM	75-3/79	209	1.72	4/79-80	95	1.67	↓ 2.9%
OR 91							
EB, R0.741-R2.60, PM	75-2/79	18	0.84	3/79-80	12	1.22	↑ 45.2%
WB, R0.430-R2.65, AM	75-3/79	11	0.43	4/79-80	5	0.45	↑ 4.7%
LA 101							
SB, 12.719-23.18, AM	75-9/79	308	1.56	10/79-80	67	1.21	↓ 22.4%
LA 170							
SB, R15.262-R17.144, AM	75-9/79	31	1.29	10/79-80	11	1.54	↑ 19.4%
LA 405							
SB, 0.884-4.94, PM	70-3/72	66	2.02	4/72-80	351	2.52	↑ 24.8%
NB, 3.24-7.24, AM	70-4/72	46	1.30	5/72-80	114	0.82	↓ 36.9%
NB, 17.556-20.18, AM	70-1972	50	1.83	1973-80	59	0.75	↓ 59.0%
NB, 30.166-38.94, PM	72-1976	255	1.61	1977-80	262	1.66	↑ 3.1%
SB, 28.892-42.26, AM	73-6/78	338	1.25	7/78-80	163	1.07	↓ 14.4%
LA 605							
NB, 1.553-13.70, AM	72-2/78	153	0.57	3/78-80	66	0.46	↓ 19.3%
SB, 1.597-16.55, PM	72-1977	313	0.99	1978-80	171	0.89	↓ 10.1%
Overall Total		3,102	1.34		2,705	1.28	↓ 4.5%

*1976 data were excluded because of the unusually high accident rates during the operation of Diamond Lanes

▲One lane (1.4 miles) was added to this section in January 1977

4.3 MAINLINE HOV LANES AND THE SAN FRANCISCO/OAKLAND BAY BRIDGE

Depending on their design, HOV lanes may or may not alleviate overall freeway congestion. When a lane is added to an existing freeway, removal of the buses and carpoools from the general traffic reduces congestion and should improve safety somewhat. When an existing lane is taken from general use to create a carpool lane, as in the use of the Santa Monica Diamond Lanes (Reference 6), congestion is likely to increase in the lanes allotted to general traffic. Whether lanes are added or existing lanes are used in creating HOV lanes, if there is no separation between the HOV lane and general traffic, the speed differentials and resultant weaving between the lanes can create a potentially hazardous situation.

4.3.1 Effect of the Carpool Lane on Safety

Accidents before and during carpool lane implementation were compared by using accident records provided by CALTRANS. Because it is often impossible to isolate the cause of any single accident, all reported accidents -- property damage, injury and fatal -- occuring in all the mainline lanes were included in the analysis. The time period and direction of flow was restricted to the peak periods and peak travel direction. (These peak periods coincided with the daily operating hours for Marin 101 and the San Francisco/Oakland Bay Bridge. Alameda 580 and the San Bernardino Busway operate essentially all day.) The dates of analysis extended as far back as 1971 in order to establish a representative sample of accidents for a pre-HOV lane baseline condition. The measure of total accidents per million vehicle miles (Acc/MVM - the accident rate) was adopted since the measure would balance out natural increases in traffic flow and allow comparisons between projects. Exhibit 4.9 summarizes accident statistics for five HOV projects. Four of the projects (Marin 101, Alameda 580, the San Bernardino Busway, and the San Francisco/Oakland Bay Bridge) were part of this enforcement study. The Santa Monica freeway results were included as an example of a project where the HOV lane was taken away from general traffic. On three of the five projects, the HOV lanes were opened first to bus traffic and later to carpool traffic, forming three distinct periods in the project's life. On the remaining two projects, Alameda 580 and the Santa Monica Diamond Lanes, the HOV lanes were opened simultaneously to carpools and buses. The comparison of accident rates centered on the time period before the HOV lane was opened to buses and the time period after the carpool opening. The period of bus-only operation was often too short to support adequate comparisons of the safety of bus-only and bus/carpool operation.

Marin 101. Accidents decreased moderately in the AM but increased by 81% in the PM period on Marin 101. An evaluation of the HOV lanes in 1977 by CALTRANS (Reference 10) could not establish the exact reason for this increase but hypothesized that the indirect effects of merging into and out of the HOV lane was a contributing factor.

Exhibit 4.9

ACCIDENT RATES FOR MAINLINE HOV LANES

Project (Direction; Time Period)	Before HOV Lane			Lanes Opened to Buses Only			Lanes Opened to Carpools			% Change in Accident Rates from Before HOV Lane to Carpool Opening
	Time Period	No. Accidents	Accidents/ MVM	Time Period	No. Accidents	Accidents/ MVM	Time Period	No. Accidents	Accidents/ MVM	
MARIN 101										
SB, 6:00-9:00 AM	71–12/74	82	1.71	1/75–3/76	28	1.79	6/76–*80	72	1.17	↓ 31%
NB, 4:00-7:00 PM		207	4.18		143	8.71		507	7.58	↑ 81%
ALAMEDA 580										
WB, 6:00-9:00 AM	72–12/77	72	1.50	—	—	—	1/78–80	15	0.52	↓ 65%
EB, 4:00-7:00 PM		68	1.67	—	—	—		32	1.29	↓ 23%
SAN BERNARDINO BUSWAY										
Separated Section										
WB, 6:00-10:00 AM	72–4/74	72	1.15	5/74–6/77	63	0.69	7/77–80	88	0.86	↓ 25%
EB, 3:00-7:00 PM		146	2.34		134	1.47		196	1.53	↓ 35%
Partially Separated Section										
WB, 6:00-10:00 AM	72	78	1.72	73–10/76	206	1.16	11/76–80	294	1.47	↓ 14%
EB, 3:00-7:00 PM		57	1.24		255	1.42		337	1.75	↑ 41%
SF/OAKLAND FREEWAY										
WB, 6:00-9:00 AM	67–4/70	112	4.86	5/70–12/71	81	7.29	1/72–80	505	8.39	↑ 73%
SANTA MONICA FREEWAY										
EB, 6:00-10:00** AM	3/75–8/75	51	1.36	—	—	—	3/76–8/76	108	4.09	↑ 201%
WB, 3:00-7:00 PM		67	1.76	—	—	—		176	5.64	↑ 221%

*Three months during bus strike not included

**Changed to 6:30 to 9:30 on 5/76

Alameda 580. Contrary to Marin 101's split trend, Alameda 580 has had a clear trend of decreased accidents during both peak periods since the HOV lanes were installed. Much of this decrease, however, can be attributed to the general roadway upgrading that was part of the HOV lane construction. In particular, the addition of a truck climbing lane in the westbound section of the freeway explains the AM's greater decrease in accident rates since the carpool lanes were opened.

San Bernardino Busway. The busway was split into the fully separated westerly section and the partially separated easterly section for the accident analysis. In the fully separated section, the accidents decreased moderately. The trend was not surprising since accidents on the busway itself are extremely rare and merging between the busway and general traffic is confined to a few points. In the partially separated section, as was observed in Marin 101, the AM accident rate dropped while the PM rate increased. In the evaluation of the bus/carpool phase of the San Bernardino Busway (Reference 15), an analysis of accidents found that the merging of carpools back into the general traffic lanes on the east end of the busway caused several accidents. A detailed breakdown of accidents revealed that the majority of these accidents were a result of illegal turning movements into or out of the busway and that busway-related accidents occurred only during the PM peak period. This merging problem would explain the PM's higher accident rate.

San Francisco/Oakland Bay Bridge. Accidents have clearly increased on the San Francisco/Oakland Bay Bridge since the HOV toll lanes were installed. The addition of the bus lane and the two carpool lanes down the middle of the facility effectively splits the toll plaza area into two halves. Carpools must merge to the center lanes before they are too close to the toll plaza or they will be stuck in the general traffic queues. Trucks may have to weave from one end of the facility to the other, an especially difficult maneuver, in order to reach the special truck toll lane. The speed differential introduced by the free flowing carpools and the queued general lanes makes the merger of carpools into the lane sometimes dangerous, and aggrevates the safety problem of illegally weaving HOV lane violators. Carpool users commonly reported that they have encountered near misses because of HOV lane violators.

The Santa Monica Freeway. The Santa Monica Freeway Diamond Lanes, a pair of concurrent-flow preferential freeway lanes for buses and carpools linking the City of Santa Monica, California with the Los Angeles Central Business District (CBD), opened on March 16, 1976, and operated amid much controversy for 21 weeks until the U.S. District Court halted the project. One of the most disturbing aspects of the project was the high incidence of freeway accidents, which increased by a factor of 2.5 times pre-project levels when the barrier-free preferential lanes were operating. A detailed analysis of accidents on the Santa Monica Freeway Diamond Lanes, which were created by removing two freeway lanes from general use and dedicating them to the exclusive use of buses and carpools, may be found in SYSTAN's evaluation of that controversial project. (Reference 6)

SYSTAN's evaluation postulated and analyzed a number of potential accident causes in an attempt to account for the pronounced increase in accident levels on the Santa Monica Freeway. Analysis of accumulated accident data pointed to several minor contributing factors, including the distracting effect of increased enforcement activities and the congestion resulting when freeway lanes were removed from general use. The most significant factors contributing to the accident increase, however, were directly related to the barrier-free design of the lanes, and found to be "The pronounced speed differential between the free-flowing traffic in the sparsely occupied preferential lane and the stop-and-go traffic in congested adjacent lanes, coupled with the frequent lane changes resulting from the variety of possible origins and destinations along the length of the project." (Reference 6)

The Santa Monica Diamond Lane evaluation went on to conclude: "Since the ability to travel faster in a preferential lane is the chief inducement for attracting carpoolers and bus users to that lane, the fact that this ability increased accident levels significantly on the Santa Monica Freeway raises serious questions regarding the feasibility of the barrier-free preferential lane in certain settings." (Reference 6)

These questions appear to exist whether the lane is created by reserving an existing lane, as was done on the Santa Monica Freeway, or by creating an entirely new lane, as was done in Marin County. Conceivably, the addition of a new barrier-free preferential lane to an existing freeway could be expected to result in increased accidents if stop-and-go traffic conditions exist in the non-preferential lane, a significant speed differential is maintained between these lanes and an underutilized preferential lane, and destinations are scattered so that carpoolers enter and exit at many points along the lane. As has been seen, accident levels increased on the barrier-free lane in Marin county even without a significant speed differential beteween the HOV lane and general traffic.

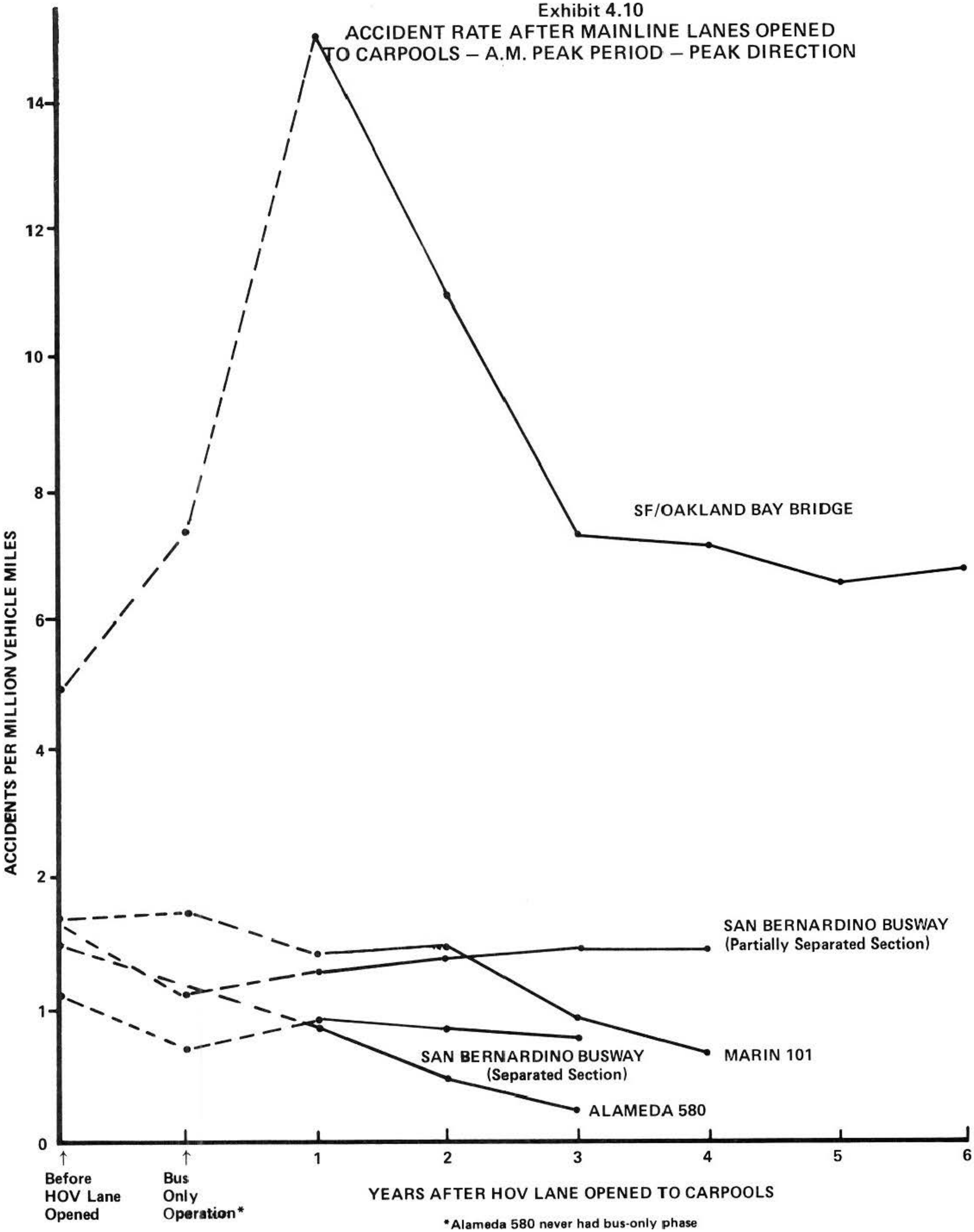
4.3.2 Accident Trends After the Lane Opened to Carpools

The projects included in this study have been in operation long enough to justify the examination of accident trends as the project matures. It was hypothesized that the accident rate would drop quickly to a stable level as drivers became accustomed to the lane. After the accident rate stabilized, it would be then possible to examine whether the accident rate would follow trends in the violation rates (i.e., whether accident rates would be high during periods of high violation rates).

The accident rates for each of the projects included in the study are presented in two graphs. The first, Exhibit 4.10, covers the AM peak period. The San Francisco/Oakland Bay Bridge is the most volatile of the locations. Accidents occured three times more often immediately after the carpool lanes were opened than before the HOV lanes were

Exhibit 4.10

ACCIDENT RATE AFTER MAINLINE LANES OPENED TO CARPOOLS – A.M. PEAK PERIOD – PEAK DIRECTION



*Alameda 580 never had bus-only phase

constructed (possible factors for this increase were discussed in the previous subsection). The accident rates declined steeply for two years and leveled out at a rate nearly 50% higher than that experienced before the construction of the HOV lanes. Accidents during the morning peak tended to go down slightly on Marin 101 and Alameda 580 after the lanes were opened to carpools and also tended to go down gradually afterwards. The San Bernardino Busway followed a slightly different trend. Accident rates dropped after bus-only operation began and stayed essentially the same over the years.

The accident rates for the PM are shown in Exhibit 4.11. Marin's PM accident rate jumped decidedly upward after the bus lane was opened to carpools and dropped steeply within a few years. Alameda 580's accidents do not follow a discernable trend. As in the AM period, the accident frequency dropped after the lanes were installed and for a few years beyond, yet the accident rate jumped upwards in the last year. (Alameda 580 would be expected to have the highest year-to-year fluctuation in accident rates because so few accidents occur along the short stretch of the HOV lane. Normally less than a dozen accidents occur each year during the evening peak.)

San Bernardino's accident rate behaves differently in the two distinct sections of freeway. Accident rates on the physically separated western section dropped, while accidents increased on the partially separated eastern section after the HOV lane was opened to bus-only operation. Accidents increased on both sections after the lane was opened to carpools and both decreased gradually afterward.

A few general trends are apparent from these graphs. Accident rates for the projects tend to increase immediately and then decrease for several years after the carpool lane is opened. Only the San Bernardino Busway during the AM period and Alameda 580 during the PM had accident rates higher in 1980 than in the first year of operation; however, these increases were negligible. In contrast, the drops in accident rates over time were sometimes dramatic. For example, the Bay Bridge's accident rate dropped from over 15 Acc/MVM to a little over 6 Acc/MVM. The stable pattern of accident rates for California freeways in general during this time period support the hypothesis that these decreases are due to a maturation process and not influenced by exogenous factors. It is somewhat surprising that the accident rate drops over a period of several years and not more quickly. Only one project -- the San Francisco/Oakland Bay Bridge -- has been opened to carpools for more than five years. After three years of operation, the accident rate dropped to a level that has been maintained for the last five years.

Projects that experienced the most dramatic increases in accident rates also had the steepest subsequent declines. The drivers seem to go through a slow learning process, adjusting fully to the HOV lane only after a few years. Accident rates appear to be less stable during the PM period, perhaps because congestion and accidents occur more frequently during the evening peak. One implication of the analysis concerns the evaluation of HOV projects. An accident analysis done

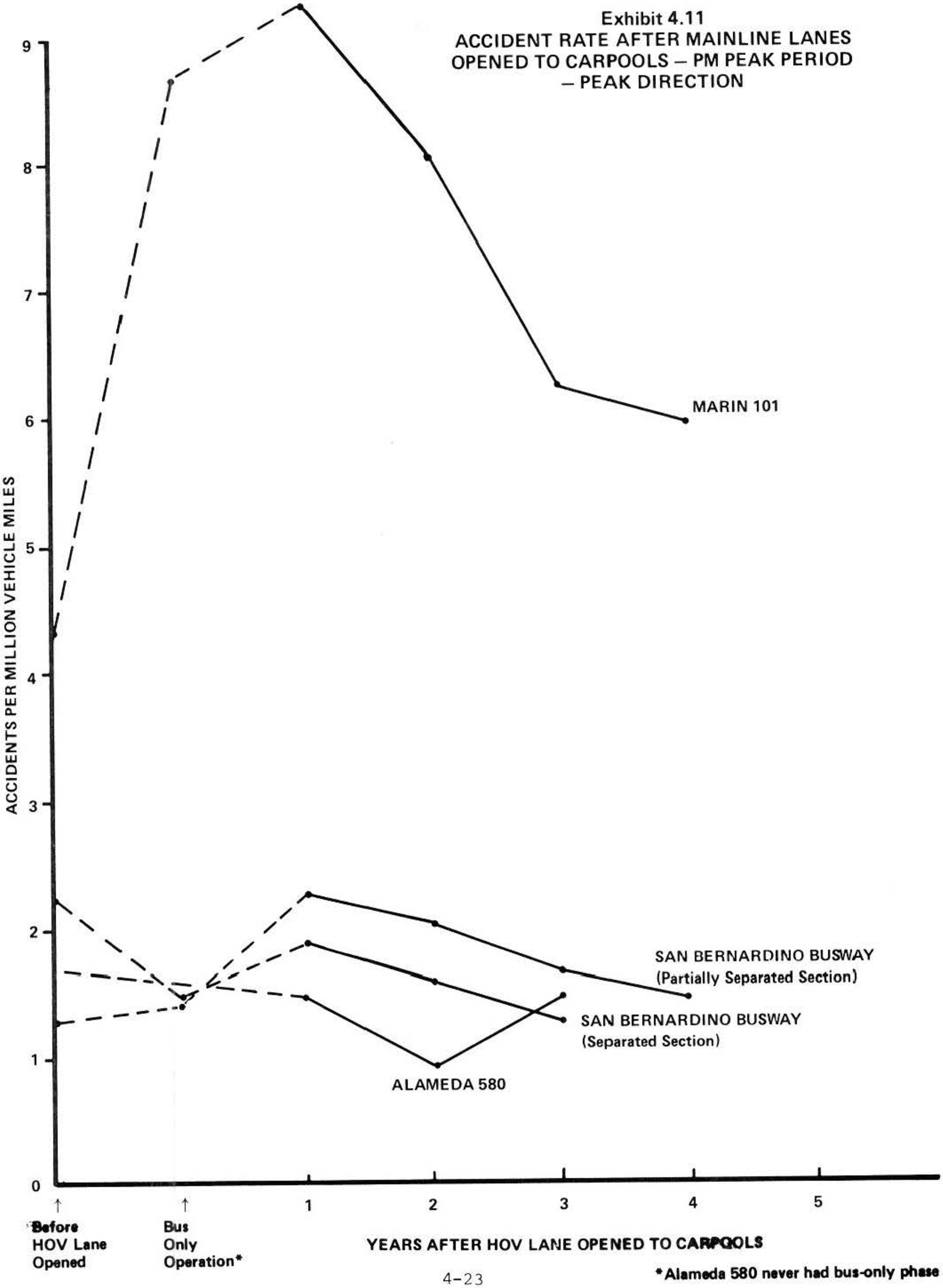


Exhibit 4.11
ACCIDENT RATE AFTER MAINLINE LANES OPENED TO CARPOOLS – PM PEAK PERIOD – PEAK DIRECTION

*Alameda 580 never had bus-only phase

soon after a project is installed will tend to overemphasize the negative impacts of projects where the accident rates increase and tend to underestimate the benefits of projects where the accident rates decrease.

4.3.3 Violations and Accidents

Accidents that can definitely be accredited to a vehicle illegally using a mainline HOV lane are rare; such accidents occur too infrequently to support general conclusions. On the Santa Monica freeway less than 10% of the accidents occuring in the Diamond Lanes themselves or on the median strip could definitely be attributed to non-carpoolers making unsafe lane changes. The actual number may have been much higher, since it is not uncommon for a vehicle changing lanes unsafely in congested conditions to escape unscathed while leaving a wave of braking vehicles in its wake. This wave may culminate in a rear-end collision well removed from the scene of the initial violation, so that the drivers involved in the collision are totally unaware of the lane change that started the chain reaction. Thus, although the unsafe actions of violators may provide a plausible explanation for certain types of accidents, it is virtually impossible to verify this explanation through a study of individual accident reports.

The tendency of mainline accident rates to decline after the first year of carpool lane operation, coupled with the tendency of untended violation rates to increase over time, makes it impossible to draw any causative correlation between violation rates and accident trends on mainline HOV projects. For instance, the Bay Bridge and the San Bernardino Busway, both with fairly stable violation rates over the years, have experienced fewer accidents recently. On Marin 101, where violation rates have risen in recent years, the accident rate has decreased, albeit perhaps more slowly than it might have if the violation rate was lower. Alameda 580's violation rates, however, have increased in recent years while the accident rate follows no clear trend. Based on the few years that the projects have been in operation, the results are inconclusive.

There are a few cautionary remarks that must be made in order to prevent a too literal interpretation of these accident rates. Accidents are, of course, unpredictable and rare events. Except for Alameda 580, the accidents occurred frequently enough to eliminate random wild fluctuations in the accident rates. The duration of bus-only operation was sometimes too short to provide adequate accident sample sizes. Finally, accidents are influenced by a multitude of factors. The gas shortages, the 55 mph speed limit, normal freeway facility upgrading and maintenance, and CHP enforcement activities will all influence the accident rate and make it difficult to draw conclusions from apparent trends.

4.4 SUMMARY

4.4.1 Metered Ramps and Bypass Lanes

For a sample of freeways under ramp control, accident rates on the freeways alone dropped 10.4%, from 1.15 accidents/MVM to 1.03 accidents/MVM following the introduction of ramp metering. At the same time, accident rates on the ramps themselves increased significantly, nearly tripling during the first year of meter control. Whereas accident rates dropped in subsequent years on ramps without bypass lanes, accidents on bypass ramps showed no sign of decline. Accident rates appeared to be highest and most persistent on ramps with high violation rates.

Even with the increases associated with metering and bypass lanes, the annual incidence of ramp accidents was relatively infrequent, averaging one accident every three years on a ramp with a bypass, and one accident every four years on a metered ramp without a bypass. This increase was not sufficient to offset the decline in freeway accidents associated with ramp control. Total system accidents after ramp metering amounted to 1.28 accidents/MVM, a decline of 4.5% below pre-metering accident rates.

4.4.2 Mainline HOV Lanes

Exhibit 4.12 summarizes accident statistics for several mainline HOV projects. Accident levels increased dramatically during the first year of operations on those three projects -- Marin 101, the Santa Monica Diamond Lanes, and the San Francisco/Oakland Bay Bridge Toll Plaza -- where there was no separation between the HOV lane and general traffic lanes. Although accident rates subsequently declined on Marin 101 and the Bay Bridge, these rates remained significantly higher than pre-project levels five years after project implementation.

On the two projects -- Alameda 580 and the San Bernardino Busway -- where the HOV lane was separated from general traffic either by a buffer lane or physical barrier, there was no upward surge in accident rates during the first year of project implementation. In fact, accident rates declined steadily on all sections of the San Bernardino freeway since the implementation of the Busway. No trends are discernable on Alameda 580, where the relatively low accident levels fluctuate from year to year.

The increases in accident rates accompanying barrier-free preferential lanes raises serious questions regarding the suitability of this design in certain settings. These questions appear to exist whether the lanes are created by reserving an existing lane, as was done on the Santa Monica freeway, or by creating an entirely new lane, as was done in Marin County. Short segments of barrier-free HOV lane operation -- as on toll plazas, ramps, and freeway-to-freeway connectors -- are not likely to generate accident increases high enough to offset the

Exhibit 4.12

SUMMARY OF ACCIDENT RATES ON MAINLINE HOV LANES

PROJECT	MORNING PEAK					EVENING PEAK				
	Before HOV	First Year of Operation		Subsequent Years		Before HOV	First Year of Operation		Subsequent Years	
	ACC/MVM	ACC/MVM	% Increase Over Before Period	ACC/MVM	% Increase Over Before Period	ACC/MVM	ACC/MVM	% Increase Over Before Period	ACC/MVM	% Increase Over Before Period
NON-SEPARATED LANES										
Marin 101	1.71	1.42	-17%	1.04	-39%	4.18	9.26	+122%	6.77	+62%
Santa Monica Freeway	1.36	4.09	+201%	*	*	1.76	5.64	+221%	*	*
SF-Oakland Bay Bridge Toll Plaza	4.86	15.08	+210%	7.58	+56%					
BUFFERED LANES										
Alameda I-580	1.50	0.90	-40%	0.32	-79%	1.67	1.49	-11%	1.18	-29%
San Bernardino Busway (eastern segment)	1.72	1.37	-20%	1.46	-15%	1.24	2.41	+94%	1.69	+36%
PHYSICALLY SEPARATE LANES										
San Bernardino Busway (western segment)	1.15	0.91	-21%	0.82	-29%	2.34	1.82	-22%	1.42	-39%

*Project discontinued after three months benefits of the carpool lane itself. Long stretches of barrier-free mainline HOV lanes operating next to stop-and-go traffic, however, can easily cause major increases in accident rates.

4.4.3 Violations and Accidents

Although violators can undermine the long-term goals of HOV lane operation, most occupancy violations pose no immediate threat to the safety of other freeway drivers. A few violators, however, represent a direct safety hazard. These include drivers who weave in and out of mainline lanes unsafely, peeking duckers who dart suddenly into the carpool bypass lane from the adjacent queue, turning wormers who stop suddenly in the bypass lane and attempt to worm their way into the adjacent queue, and conscience-stricken violators who stop unnecessarily at the head of an unmetered carpool lane to observe the meter in the adjacent lane. While increased enforcement caused the incidence of weaving activities to decrease on mainline HOV lanes, it actually brought about an increase in the evasive actions taken on ramp bypass lanes by peeking duckers and turning wormers.

Accidents that could definitely be attributed to a vehicle illegally using an HOV lane were rare, and occurred too infrequently to support general conclusions. Similarly, the general unpredictability of accident rates made it impossible to draw any causative correlation between violation rates and accident trends on mainline HOV lanes. In the case of ramp bypass lanes, however, accidents rose to higher levels and remained higher longer on ramps with high violation rates.

5. DRIVER ATTITUDES AND PUBLIC INFORMATION

This chapter addresses the attitudes of California drivers toward preferential lane projects, as revealed in surveys mailed to a sampling of violators, carpoolers, and general drivers observed on HOV projects throughout the state before and after special enforcement efforts. The mechanics of the survey process are summarized, and driver attitudes toward such topics as enforcement, violations, preferential lanes for carpoolers, and ramp metering are tabulated and analyzed. Differences between violators and non-violators are explored, both through survey responses and through an examination of past driving records. Public information programs and media coverage of HOV projects are discussed, and the impact of a specific media campaign on violation rates is investigated.

5.1 SURVEY FINDINGS

5.1.1 Survey Procedures

Significant numbers of single drivers, carpoolers, and carpool-lane violators on a variety of HOV projects were surveyed at two points in the study: (1) At the beginning of the study, just prior to the first wave of special enforcement, and (2) At the end of the study, during the fourth wave of special enforcement. The populations surveyed were contacted by sampling the license plates of vehicles in carpool lanes and adjacent lanes, using DMV records to obtain the addresses of vehicle owners and mailing surveys to the owners' homes. The beginning survey addressed a wide range of topics, including individual travel characteristics, carpool lane use, experiences with ramp metering, perceptions of enforcement, demographic data, and opinions regarding future transportation needs. The ending survey was significantly shorter, focusing on HOV lane enforcement in an attempt to document any changes in perceptions and attitudes which might have occurred as a result of a year of special enforcement activity. Copies of the basic survey forms can be found in Appendix 7.

Projects Surveyed. In the course of the study, surveys were mailed to a sample of single drivers, carpoolers, and carpool-lane violators on three mainline HOV lanes: the San Francisco/Oakland Bay Bridge; six ramp meter bypass lanes in Los Angeles; two bypass lanes on freeway-to-freeway connectors in San Diego; and two newly installed ramp meter bypass lanes in San Jose and San Diego. A list of the projects surveyed appears below:

PROJECT	EARLY SURVEY	LATE SURVEY
MAINLINE HOV LANES		
Alameda 580	X	X
Marin 101	X	X
San Bernardino Busway	X	
SF/OAKLAND BAY BRIDGE	X	X
RAMP METER BYPASS LANES		
Los Angeles		
National (AL10)	X	X
Vernon (LA11)	X	X
Colorado (LA5)	X	X
Woodman (LA101)	X	X
Olympic/Pico (LA405)	X	X
Orangethorpe (OR91)	X	X
San Diego		
I-15 to SR94	X	X
I-805 to SR94	X	X
El Cajon (I8)		X
San Jose		
Guadalupe Expressway (SC101)	X	X

Surveys were printed separately for each project, and color-coded so that the responses of violators, carpoolers, and general drivers could be analyzed independently. To ensure the anonymnity of respondents, no attempt was made to link the surveys to a particular driver.

Survey Return Rate. The overall response rate for all projects averaged 22.9% for the first survey, and 29.2% for the second, shorter, survey. Exhibit 5.1 tabulates overall response for the various project categories. The highest response rate came from drivers responding to the second survey on Alameda 580 (43.3%), followed by the San Francisco/Oakland Bay Bridge (43.1%). Among the three user types, carpoolers led with a 28.9% overall return rate. The corresponding figures for general users and violators were 26.9% and 18.9%, respectively.

Appendix G tabulates the survey mailings and response rates for individual projects. On the mainline HOV lanes, combined response rates to both surveys were lowest among violators on Marin 101 and the San Bernardino Busway (14.5% and 7.3%, respectively). Violators on Alameda 580, however, exhibited no reluctance to respond to the survey, taking the opportunity to express their dissatisfaction with CALTRANS in general and the preferential lanes in particular (27.5% of the Alameda 580 violators contacted responded to the two surveys). Among the six Los Angeles ramps, drivers using the Vernon Avenue ramp on the Harbor Freeway (LA 11) were least responsive, with an overall response rate of 12.5%, while the other five ramps each had response rates of over 20%. Although there was no significant difference in the overall response rate among user types on Los Angeles ramps, violators on San Diego and

Exhibit 5.1

SURVEY RESPONSE RATES

Project Type	Early Survey Survey Category				Late Survey Survey Category			
	Violators	Carpoolers	General Traffic	Total	Violators	Carpoolers	General Traffic	Total
MAINLINE HOV LANES								
Surveys Delivered	683	1,305	1,449	3,437	182	769	934	1,885
Surveys Returned	94	302	375	771	60	300	370	730
% Returned	13.8%	23.1%	25.9%	22.4%	33.0%	39.0%	39.6%	38.7%
SF/OAKLAND BAY BRIDGE								
Surveys Delivered	254	499	960	1,713	92	2,401	993	3,486
Surveys Returned	38	171	264	473	29	1,124	348	1,501
% Returned	15.0%	34.3%	27.5%	27.6%	31.2%	46.8%	35.0%	43.1%
LOS ANGELES RAMPS								
Surveys Delivered	1,501	1,462	3,503	6,466	900	3,144	4,942	8,986
Surveys Returned	339	296	992	1,627	199	818	1,547	2,564
% Returned	22.6%	20.3%	28.3%	25.2%	22.7%	26.0%	31.3%	28.5%
SAN DIEGO RAMPS								
Surveys Delivered	178	815	2,341	3,334	123	1,875	5,467	7,465
Surveys Returned	14	140	398	552	11	349	1,157	1,517*
% Returned	7.9%	17.2%	17.0%	16.6%	8.9%	18.6%	21.2%	20.3%
SAN JOSE RAMPS								
Surveys Delivered	360	200	760	1,320	252	208	785	1,245
Surveys Returned	36	53	220	309	41	110	282	433
% Returned	10.0%	26.5%	28.9%	23.4%	16.3%	52.9%	35.9%	34.8%
TOTAL								
Surveys Delivered	2,976	4,281	9,013	16,270	1,549	8,397	13,121	23,067
Surveys Returned	521	962	2,249	3,732	340	2,701	3,704	6,745
% Returned	17.5%	22.5%	25.0%	22.9%	21.9%	32.2%	28.2%	29.2%

*Reflects surveys returned four weeks after mailing

San Jose ramps (8.3% and 12.6%, respectively) were less responsive than carpoolers and general users.

General Findings.

In general, the tabulated survey responses seem to indicate that although the differences between violators, carpoolers and general users on a particular project are few and generally predictable, there are major differences separating the attitudes and perceptions of users of individual projects. This was especially true on the mainline HOV lanes, with all classes of drivers on Alameda 580 viewing the preferential lanes unfavorably, while drivers using Marin 101 and the San Bernardino Busway were generally more tolerant of HOV projects.

This finding reflects the diversity of attitudes recorded in past surveys conducted on individual projects. SYSTAN's survey of drivers in the Santa Monica Freeway corridor during the controversial Diamond Lane demonstration in 1976 (Reference 6) showed that eighty-six percent of the drivers surveyed, including the majority of carpoolers felt that the Santa Monica Diamond Lanes were either harmful or of no use whatsoever. A subsequent survey of drivers in the San Bernardino Freeway corridor to the west of the Santa Monica Corridor, on the other hand, showed overwhelming support for both the San Bernardino Busway and the concept of HOV lanes among carpoolers and non-carpoolers alike. (Reference 15)

The similarity of responses from violators, carpoolers, and general drivers on individual projects may have been influenced by a non-respondent bias. That is, it is possible that people who are willing to respond to mail surveys think alike on the topics at issue, while those who fail to respond think differently. Because the survey was structured to guarantee the anonynimity of the respondent, there was no way to check whether the respondents constituted a representative sampling of the population at large. However, the average response rates to the second survey approached 30% and exceeded 40% on some projects. Moreover, the similarity of violators and non-violators is borne out by the low incidence of repeat violations (Section 5.4.3) which suggests a large percentage of the project users violate at one time or another.

5.1.2 Awareness of Enforcement

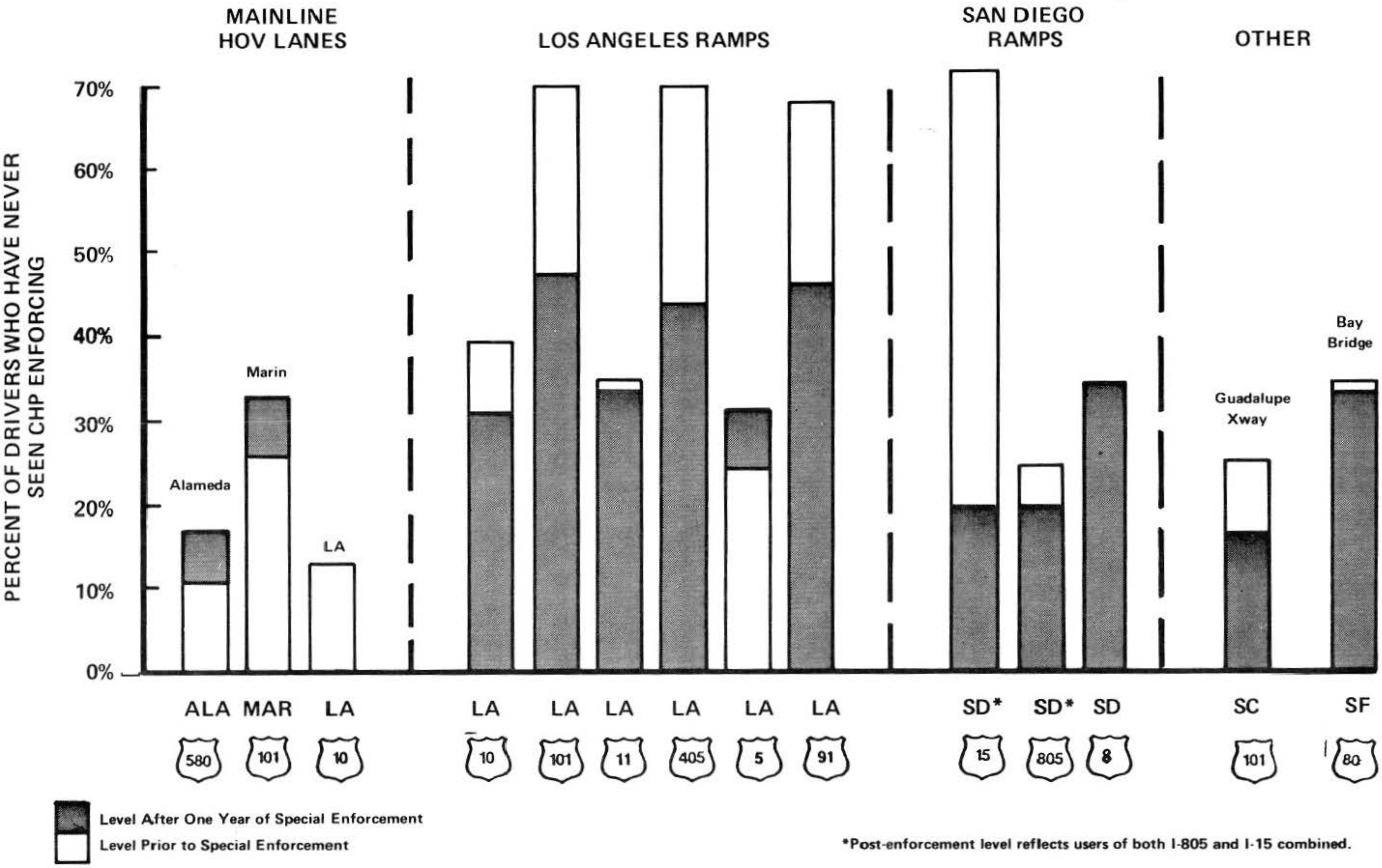
One of the major differences among the projects themselves may be found in driver awareness of enforcement, as measured by the response to the question "Have you ever seen the Highway Patrol stopping a driver for using the bus/carpool lane without the proper number of occupants?" At the start of the study, the perceived level of overall enforcement was much higher on the mainline HOV lanes than on the sample ramp bypass lanes in Los Angeles, San Diego, and San Jose. While only 14% of the mainline HOV lane users said that they had never seen the CHP enforcing occupancy violations, 24% of the Guadalupe Expressway drivers, 38% of the San Diego ramp users and fully half of the Los Angeles ramp users responded that way. Exhibit 5.2 graphs the awareness of enforcement on each project before and after several waves of special enforcement were introduced.

Mainline HOV Lanes. Among the three mainline HOV lanes, the perceived enforcement level is relatively lower on Marin 101 than on the San Bernardino Busway and Alameda 580. Prior to the start of the study, only 13% of the respondents on the San Bernardino Busway, where violators tend to be apprehended and ticketed in the buffer lane reported that they had never seen the CHP ticketing violators. On Marin 101, where the CHP must escort violators to the side of the freeway before issuing citations, 26% of all respondents reported that they had never seen an occupancy citation issued. These relative levels of enforcement awareness had not changed appreciably by the end of the study, even though enforcement levels in Marin had increased significantly (by the end of the study, officers were routinely issuing 18 citations per day on Marin 101 -- see Section 2.2.2). In spite of these increases, 33.4% of Marin 101 drivers still reported they had never seen an occupancy citation issued.

Los Angeles Ramps. The six sample Los Angeles ramps also differ markedly in the amount of enforcement perceived by drivers. Prior to the start of the study, over sixty percent of the respondents on the National (LA 10), Vernon (LA 11), and Colorado (LA 5) ramps reported seeing the CHP ticketing occupancy violators at least once, while only one-third of the respondents on the Woodman (LA 101), Olympic/Pico (LA 405), and Orangethorpe (LA 91) ramps had ever seen a citation issued. These differences in driver awareness mirrored the relative differences between historical levels of routine enforcement on each ramp. The citation rates recorded during the pre-enforcement period were relatively low on the Woodman, Orangethorpe and Olympic/Pico on-ramps (.03, 0 and .56 citations per day, respectively), where drivers were relatively unaware of enforcement activities. On the National, Vernon and Colorado on-ramps, however, the citation levels were considerably higher (.58, .83 and .95 citations per day, respectively). The length of time the individual bypass lanes had been in operation may also contribute to the marked differences in driver awareness of enforcement. The two newest bypass lanes surveyed, Orangethorpe and Woodman, ranked lowest in perceived enforcement levels. Each of the sample ramps in Los Angeles had a refuge area beyond the meter where officers stood to issue citations, so the manner in which violators were apprehended was judged not to be a factor in explaining the differences in driver awareness.

After a year of special enforcement activities, the percentage of drivers who had never seen a ticket issued for an occupancy violation dropped from around seventy percent to just under fifty percent on those three Los Angeles ramps (Woodman, Orangethorpe, and Olympic/Pico) where drivers had been least aware of enforcement. In one sense, it is gratifying to see that the special enforcement activities had a measurable impact on driver awareness on these ramps. In another sense, however, it is sobering to recognize that after a total of 50 days of special enforcement on these ramps, during which 750 citations were issued, nearly half of the drivers using the ramps remained oblivious to the existence of any enforcement activity whatever.

Exhibit 5.2
AWARENESS OF ENFORCEMENT



*Post-enforcement level reflects users of both I-805 and I-15 combined.

After a year of special enforcement activities, driver awareness of enforcement also increased slightly on two of the three remaining Los Angeles ramps. On the National and Vernon ramps, the percentage of drivers reporting they had never seen an occupancy citation issued dropped to around 33% from 39% and 34%, respectively. On the Colorado ramp on the Golden State Freeway, this percentage actually rose from 25.0% to 31.7% in the course of the study.

San Diego Ramps. Drivers on the I-805 interchange in San Diego differed significantly from their counterparts on the I-15 interchange in their perception of enforcement levels prior to the start of special enforcement. While only a quarter of the respondents on I-805 had never seen the CHP enforcing, over 70% of the respondents on I-15 reported that they had never seen a citation issued for illegal use of the carpool lane. Historical citation rates on both of these ramps were relatively low. However, the I-805 interchange has an ample refuge area where CHP officers may stand and wave over violators in full view of other drivers using the ramp. By way of contrast, the refuge area available for citing offenders on the I-15 interchange is scanty, so that officers often have to pursue violators and cite them some distance away from the ramp itself. After three waves of special enforcement on both ramps, driver awareness of enforcement had increased markedly on the I-15 ramp, and only 20.1% of the respondents from both interchanges reported that they had never seen the CHP enforcing bypass lane restrictions.

San Francisco/Oakland Bay Bridge. On the Bay Bridge, 30.1% of the drivers responding to the initial survey and 32.0% responding to the final survey, reported that they had never seen the CHP enforcing the carpool lane. While these percentages are comparable with those reported on ramp meter bypass lanes, they are surprisingly high in comparison with the awareness levels on mainline lanes, especially in view of the relatively long life of the preferential bridge lane, and the citation history, which averaged 2.4 tickets per day just prior to the initiation of special enforcement actions and five to 16 tickets per day during special enforcement. One explanation for the lack of awareness of enforcement actions is the tendency of some officers to pursue violators and issue tickets at locations well removed from the toll plaza itself. In addition, the large number of lanes at the toll plaza tends to shield many drivers from enforcement activities taking place in the carpool lane.

Guadalupe Expressway. Prior to the start of special enforcement, only 24.4% of the drivers using the Guadalupe Expressway ramp leading to the northbound Bayshore Freeway in San Jose reported that they had never seen the CHP enforcing the lane's occupancy restrictions. This level reflects an initial driver awareness equal to that of any of the bypass lanes surveyed, and is particularly surprising, since the initial survey was conducted at a time when the ramp was newly opened and a jurisdictional dispute between the San Jose city police and the CHP left the lane largely unenforced. Evidently a few CHP officers and San Jose city police enforced the ramp during the jurisdictional dispute, and their presence was noted by the drivers waiting in the long lines at the ramp meter.

By the close of the study, the combination of routine and special enforcement actions had caused the percentage of drivers unaware of any enforcement to drop to 15.4%, the lowest percentage reported on any bypass lane. It is likely that the long wait encountered in the metered lanes (an average of 7.8 minutes per day) causes drivers to be more aware of enforcement on the Guadalupe Expressway ramp than on other ramps.

5.1.3 Perceived Changes in Enforcement

The post-enforcement survey posed the following question to drivers using the sample projects:

> "During the past year, do you feel that Highway Patrol enforcement of special bus and carpool lanes has:
>
> ( ) increased ( ) decreased ( ) stayed about the same

Exhibit 5.3 summarizes the responses elicited from drivers on individual projects, which were remarkedly similar. The percentage of drivers who felt that enforcement had increased formed a tight range between 17.6% and 26%, and was significantly higher than the percentage who perceived a decrease on all projects except Alameda 580 and the Guadalupe Expressway.

Attempts to interpret driver's perceptions of changes in enforcement are colored by the surprisingly high proportion of drivers who had never seen any occupancy violators cited and who, therefore, reported perceiving "no change" in enforcement levels.

Driver perceptions of enforcement changes somewhat parallel their opinions regarding the need for change, as expressed in the pre-enforcement survey. When asked prior to the study whether they agreed with the statement "The Highway Patrol should enforce bus and carpool lanes more often," 69.3% of all drivers agreed with the statement, 11.6% disagreed, and 19.1% were indifferent. Reactions tended to be similar from project to project, except on the controversial Alameda 580 preferential lanes, where 33% of all drivers surveyed felt that there was no need for additional enforcement (see Reference 4).

5.1.4 Perceived Violation Levels

The violation levels perceived by drivers varied less from project to project than their perceptions of enforcement levels. When asked, "What percentage of the drivers in the bus/carpool lane would you estimate use the lane illegally?", drivers responded with average estimates within a limited range which tended to overestimate low rates and underestimate high rates. Drivers on mainline HOV lanes

Exhibit 5.3

PERCEIVED CHANGES IN ENFORCEMENT REPORTED BY DRIVERS AFTER A YEAR OF SELECTIVE ENFORCEMENT ACTIONS

Project	Perceived Enforcement Change (all drivers)		
	Increased (%)	Decreased (%)	No Change (%)
MAINLINE HOV LANES			
Alameda 580	17.6	21.2	61.2
Marin 101	20.7	6.1	73.2
SF/OAKLAND BAY BRIDGE	21.8	19.3	58.9
LOS ANGELES RAMPS			
National	26.0	12.8	61.2
Woodman	21.3	9.2	69.5
Vernon	25.9	10.3	63.8
Olympic/Pico	24.7	8.5	66.8
Colorado	24.6	8.4	67.9
Orangethorpe	22.2	9.6	68.2
SAN JOSE RAMP			
Guadalupe	25.9	26.8	47.3
TOTAL	23.5%	13.6%	62.9%

consistently over-estimated the actual violation rates existing prior to special enforcement efforts.[1] Los Angeles drivers asked to estimate the relative number of bypass lane violators tended to underestimate the relatively high levels existing prior to special enforcement, while San Diego drivers guessed that the lane violation rates on the I-15 and I-805 interchange were higher than the relatively low rates computed from roadside observations.

Exhibit 5.4 compares lane violation rates estimated by drivers with the actual rates measured during the pre-enforcement period. Driver's estimates of violation rates were of the same rough order of magnitude as the actual violation rates, indicating that drivers had a fair awareness of the illegal use of HOV lanes. An attempt to rank the surveyed ramps from high to low on the basis of violation rates would have resulted in roughly the same rankings whether driver estimates or actual pre-enforcement counts were used. Driver estimates formed a tighter range than the actual lane violation rates,[2] however, since drivers tended to over-estimate low violation rates and underestimate high rates.

While the violation estimates provided by violators, carpoolers, and general drivers did not differ significantly (at the .05 level of statistical significance) from each other on any project, the violation rates cited by violators tended to be higher than those cited by carpoolers and other drivers. These higher estimates may reflect the tendency for respondents to perceive what they want to believe. It is undoubtedly more comfortable for violators to believe that they are not the only ones violating, that "everybody does it." This belief could lead violators to perceive and report higher violation rates than law-abiding citizens.

<u>Perceived Post-Enforcement Violation Rates</u>. The special enforcement forays launched during this study had their largest impact on the ramp meter bypass lanes of Los Angeles. Violation rates on five of the six Los Angeles ramps included in the survey sample dropped significantly as a result of special enforcement. Exhibit 5.5 compares lane violation rates on these ramps before and after special enforcement with driver estimates of lane violation rates during the corresponding time periods. Whereas the actual lane violation rates on the six ramps dropped markedly from an average of 35.2% before special enforcement to 24.1% after special enforcement (a drop of 32.5%), the perceived lane violation rates reported by drivers dropped less precipitously, from

---

[1] On Marin 101, drivers underestimated the actual violation rate existing just prior to the special enforcement program. However, violation rates had recently increased as ticketing activity declined, so that driver estimate of violation rates were actually higher than the relatively low historical levels.

[2] Average violation rates estimated by drivers ranged from 15.9% (Marin 101) to 36.0% (Alameda 580), while actual rates ranged from 8.9% (San Bernardino Busway) to 48.2% (National Boulevard ramp on LA 10).

Exhibit 5.4

COMPARISON OF RESPONDENTS' ESTIMATE OF LANE VIOLATION RATE VS. ACTUAL LANE VIOLATION RATE

(Pre-Enforcement Period)

	Respondents' Estimate of Lane Violation Rate (%)	Actual Lane Violation Rate (%)	Difference (Estimated-Actual) (%)
MAINLINE HOV LANES			
Alameda 580	36.0	30.6	+5.4
Marin 101	15.9	21.8	−5.9*
San Bernardino Freeway (LA 10)	16.0	8.9	+7.1*
LOS ANGELES RAMPS			
National (LA 10)	30.0	48.2	−18.2*
Woodman (LA 101)	23.0	35.9	−12.9*
Vernon (LA 11)	27.3	33.4	−5.1
Olympic/Pico (LA 405)	31.4	47.7	−16.3*
Colorado (LA 5)	19.9	13.4	+6.5
Orangethorpe (OR 91)	27.9	32.7	−4.8
SAN DIEGO RAMPS			
I-15 – Rt. 94	31.4	25.9	+5.5
I-805 – Rt. 94	20.4	17.6	+2.8

*Indicates difference between estimated and actual rates is statistically significant (at 0.05 level of significance)

Exhibit 5.5

COMPARISON OF ESTIMATED AND ACTUAL LANE VIOLATION RATES
(Before and After Special Enforcement)

Ramp	Route	Pre-Enforcement (May 1980)		Post-Enforcement (September 1981)	
		Driver Estimates LVR (%)	Measured Rates LVR (%)	Driver Estimates LVR (%)	Measured Rates LVR (%)
National	(LA 10)	30.0	48.2	22.2	32.9
Woodman	(LA 101)	23.0	35.9	21.5	20.3
Vernon	(LA 11)	27.3	33.4	26.1	23.8
Olympic/Pico	(LA 405)	31.4	47.7	25.0	30.7
Colorado	(LA 5)	19.9	13.4	23.8	17.3
Orangethorpe	(OR 91)	27.9	32.7	25.8	19.7
Average Lane Violation Rates		26.6	35.2	24.1	24.1
Corresponding Ramp Violation Rates		–	11.8	–	6.2

26.6% to 24.1% (a drop of 9.4%). In all cases, however, driver estimates reflected the actual direction of change. Drivers reported lower post-enforcement estimates on the five ramps where observations showed violation rates to have dropped, and higher estimates on the one ramp (Colorado on I-5), where violation rates actually increased.

There are several reasons why driver estimates of the decline in violation rates might be more conservative than the actual drops: (1) As violation rates drop, ramp delays increase, so that non-carpoolers spend more time on the ramp and are more likely to see those violators who persist (see Section 2.1.7). (2) Drivers responding to a request for an estimate of current violation rates will probably be influenced by past history. If violation rates have been higher in the past, their estimates will be correspondingly higher.

Following special enforcement, drivers continued to overestimate violation rates on low-violation ramps and under-estimate violation rates on high-violation rates, so that the average post-enforcement driver estimate exactly equaled the observed post-enforcement violation rate of 24.1% on the six sample ramps. Driver estimates of violation rates varied little from ramp to ramp, ranging from 21.5% to 26.1% on the six ramps, while actual violation rates ranged from 17.3% to 32.9%, and post-enforcement comparisons showed even less correlation between actual and estimated values than pre-enforcement comparisons. While drivers appeared to be somewhat sensitive to major improvements in the violation picture, it is unlikely that they would be able to detect changes in the range below a 25% lane violation rate (roughly a 6.5% ramp violation rate).

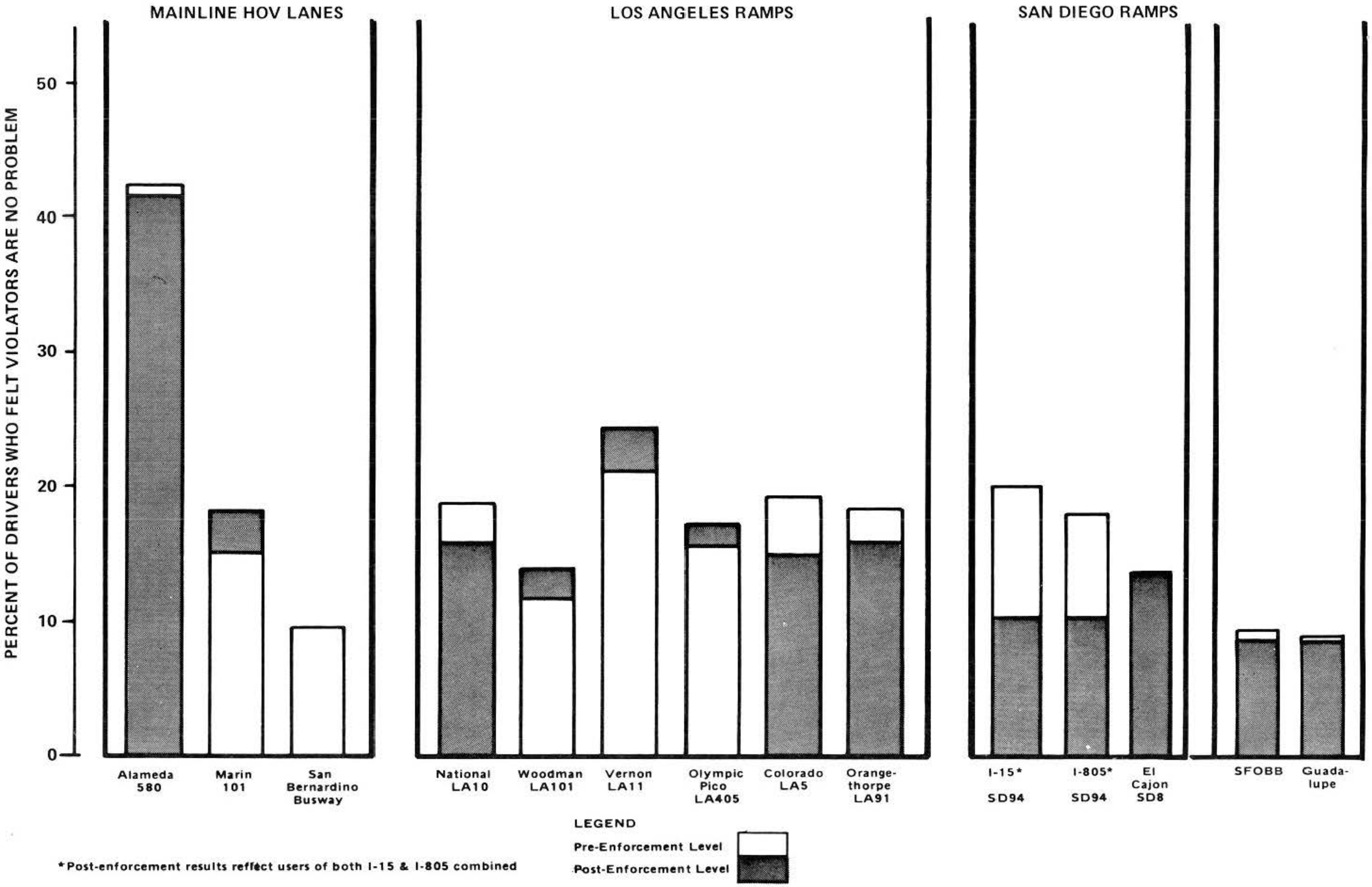
5.1.5 Attitudes Toward Violations

Exhibit 5.6 charts the pre- and post-enforcement responses of drivers on different projects to the question:

> "Do you feel that the use of the bus/carpool lane by
> non-carpoolers is a:
> ( ) serious problem
> ( ) minor problem
> ( ) no problem
> ( ) other ______________________"

The relative attitudes of drivers toward the seriousness of violations did not change appreciably in the course of the study. Of all the projects surveyed, drivers on Alameda 580 were least concerned about the presence of violators. Forty-three percent of Alameda drivers responding to the pre-enforcement survey felt that violators were "no problem." Over 55% of the drivers on all other projects except the Guadalupe Expressway and the San Bernardino Busway consistently felt that violators were only a minor problem. On the Guadalupe Expressway, 45.2% of all drivers (including 55% of all carpoolers) felt that violations posed a serious problem, while on the San Bernardino Busway,

Exhibit 5.6
RESPONDENTS' ATTITUDE TOWARDS LANE VIOLATORS



*Post-enforcement results reffect users of both I-15 & I-805 combined

33.9% of all drivers (including 39% of all carpoolers) felt the problem was serious. There were no significant differences separating the attitudes of violators, carpoolers, and general drivers toward the seriousness of violations on ramp bypass lanes in Los Angeles and San Diego. On mainline HOV lanes, where weaving violators could pose a safety hazard, and on the Guadalupe Expressway and the San Francisco/Oakland Bay Bridge, carpoolers tended to view violations in a more serious light than general drivers, while violators underrated the seriousness of their actions.

5.1.6 Attitudes Towards Ramp Metering

Since it is possible that violations on metered ramps may stem from a disenchantment with the metering system itself, all drivers contacted in the pre-enforcement survey were asked their opinion regarding the need for more freeway metering, while users of metered ramps were asked specific questions regarding their experiences with ramp delays and congestion on metered freeways (see Sample Survey Form, Appendix F).

Driver Opinions. Drivers on the three mainline HOV lanes were much less favorably disposed towards ramp metering than the ramp users in Los Angeles and San Diego. Alameda 580 drivers were least favorable with 52.5% of those surveyed feeling that no more ramp meters should be installed, followed by Marin 101 (44.0%) and San Bernardino Busway (40.2%). By way of contrast, less than one-third of the on-ramp users in Los Angeles and San Diego echoed that sentiment. Thus drivers having direct experience with ramp metering tended to be more favorably disposed toward the concept.

Perceived Travel Time Savings. Overall survey responses seem to indicate that ramp users have mixed feelings on the benefits of ramp metering. While 70% of Los Angeles ramp users and 66% of San Diego ramp users agreed that metering had improved freeway flow, only 14% of all Los Angeles respondents and 21% of their counterparts in San Diego felt that metering had shortened their overall trip time. Over half of all ramp users felt that ramp metering had no effect on their overall travel time while one-third of them believed that it had actually increased their travel time. Exhibit 5.7 summarizes these findings for the sample ramps in Los Angeles.

5.1.7 Attitudes Toward Preferential Carpool Lanes

Driver Opinions.

Exhibit 5.8 charts the percentage of drivers on each project who disagreed with the statements "More special freeway lanes are needed for carpoolers" and "Carpools should be allowed to bypass stop lights on freeway entry ramps." Of all the sample projects, drivers on Alameda 580 viewed the concept of preferential freeway lanes least favorably,

Exhibit 5.7

PERCEPTIONS OF RAMP METERING (LOS ANGELES)

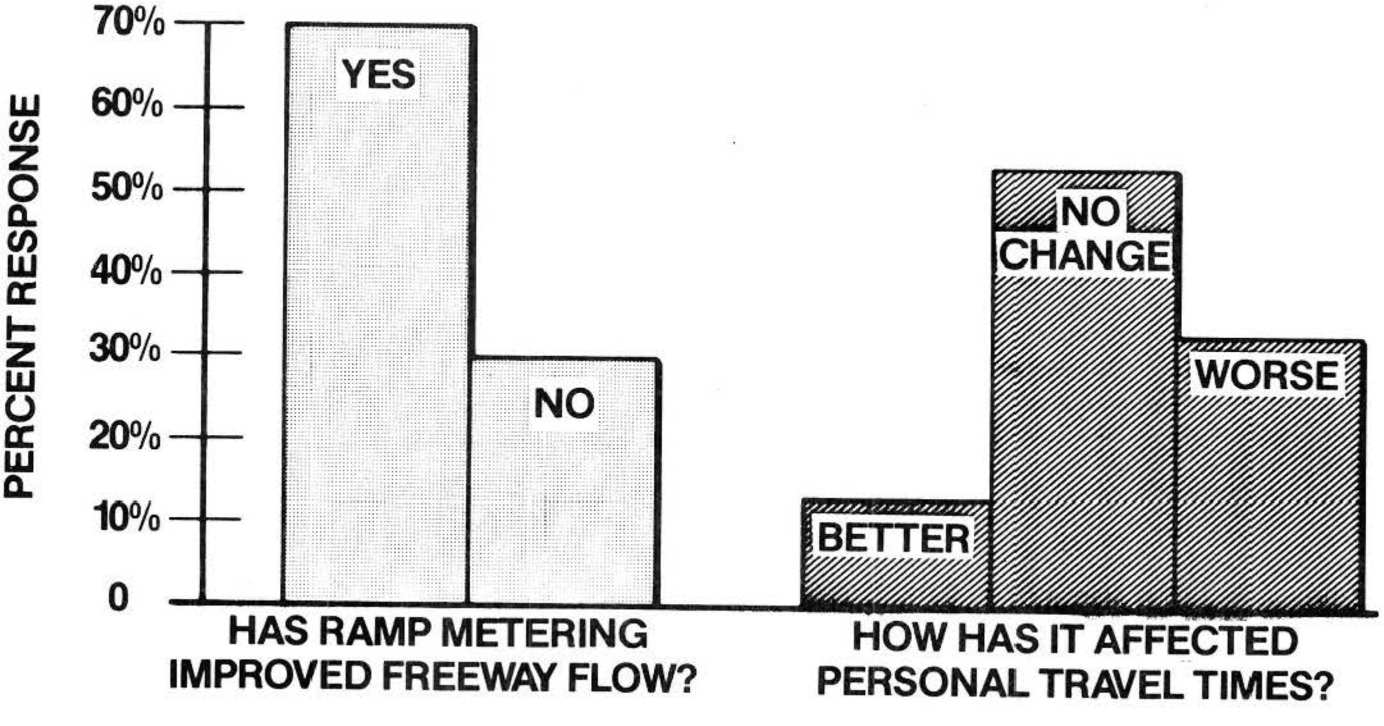
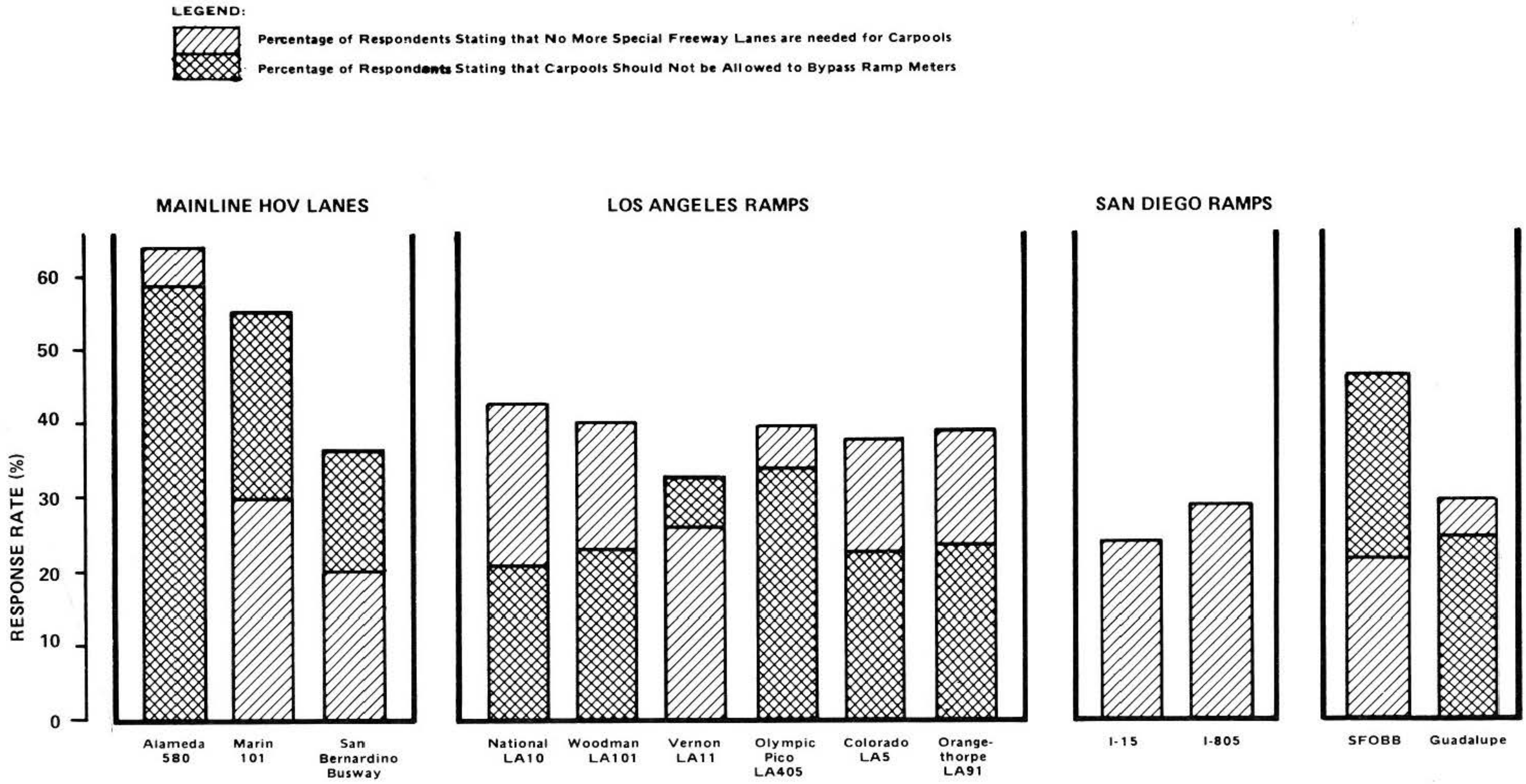


Exhibit 5.8

DRIVERS' ATTITUDES TOWARD PREFERENTIAL CARPOOL LANES



with nearly 60% of all drivers (including 37% of all carpoolers) disagreeing with the need for more carpool lanes on freeways. Most of these dissenters expressed strong disagreement with the HOV concept, reflecting the adverse media publicity and public hostility directed toward the Alameda 580 project.

By way of contrast, relatively few drivers on Marin 101 or the San Bernardino Freeway opposed the idea of more freeway lanes for carpools. Among the users of ramp bypass lanes, San Diego drivers viewed the idea of dedicated freeway lanes more favorably than Los Angeles drivers. Los Angeles opposition may stem from the much-publicized controversy surrounding the ill-fated Santa Monica Freeway Diamond Lanes in 1976 (see Reference 6). Of the six Los Angeles freeway ramps surveyed, opposition to special freeway lanes was the strongest on the National Boulevard ramp leading to the Santa Monica Freeway.

Users of the six sample ramps in Los Angeles varied slightly in their attitudes towards ramp bypass lanes. While less than one-quarter of all users on Colorado (LA 5), Woodman (LA 101), Orangethorpe (LA 91), and National (LA 10) thought that carpools should <u>not</u> be allowed to bypass ramp meters, over one-third of the users on Vernon (LA 11) and Olympic/Pico (LA 405) felt that way. The corresponding figures for the three mainline HOV lanes were much higher, with over half of Alameda 580 and Marin 101 respondents objecting to ramp bypass lanes for carpoolers. The lack of first-hand experience with ramp bypass lanes may contribute in part to the overwhelmingly negative attitudes of Marin 101 and Alameda 580 respondents towards ramp bypass lanes. Even so, 37% of the respondents using the San Bernardino Freeway, who are more likely to have had direct experience with ramp bypass lanes, objected to the concept of carpool bypass lanes.

<u>Perceived Time Savings</u>. Drivers on both mainline HOV lanes and sample ramps with bypass lanes were asked how much time they save by using the preferential carpool lanes. Tabulations of results show that drivers responding to this question wildly over-estimated the time saved by using the carpool lanes.

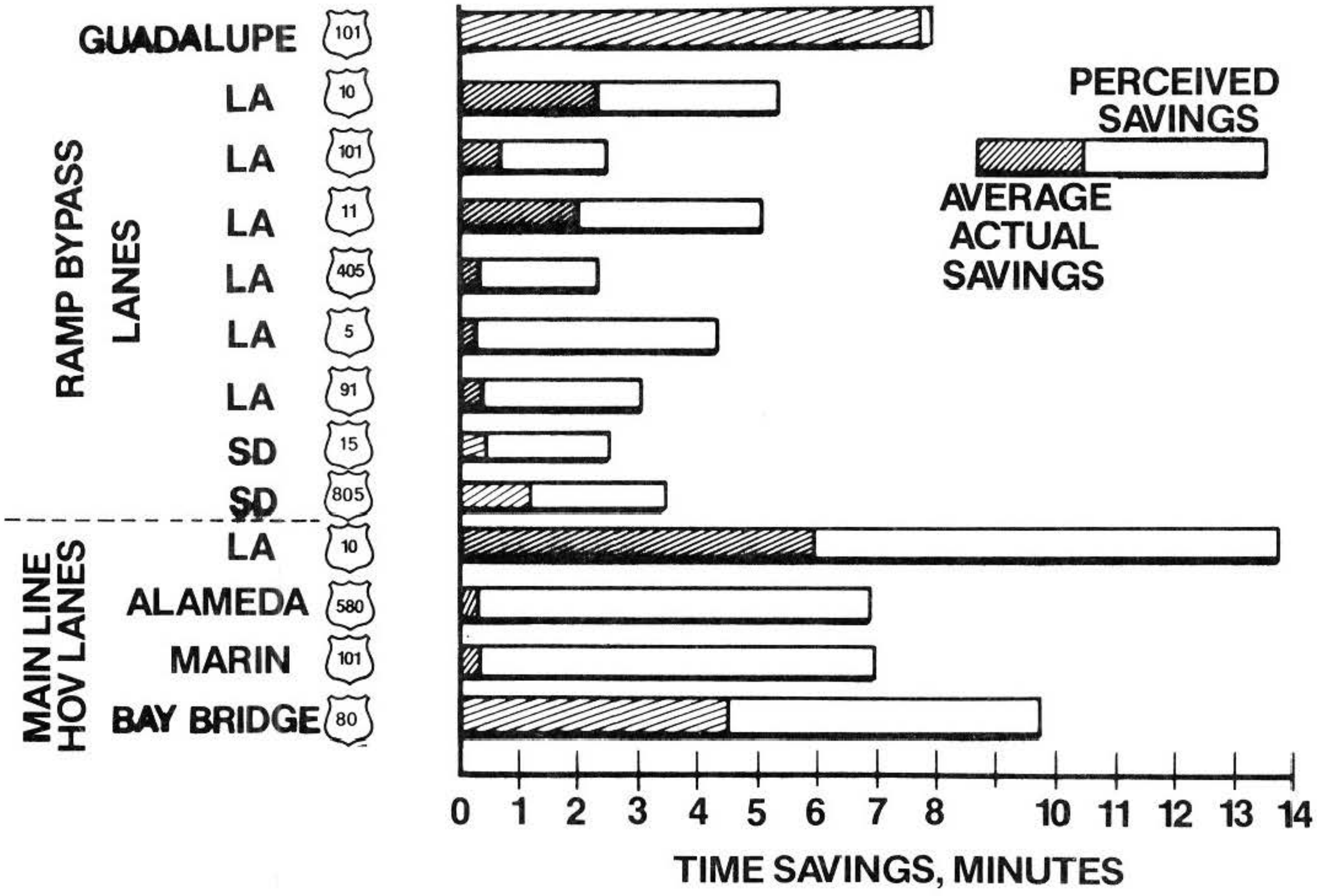
Exhibit 5.9 compares actual and perceived time savings on the projects included in the pre-enforcement survey. On each of these projects, violators, carpoolers, and general drivers alike greatly over-estimated the average time savings available to carpoolers.

While there were no perceptible differences between the estimates of different types of drivers, perceptions of time savings differed significantly from lane to lane and ramp to ramp. Drivers on the National and Vernon ramps perceived greater time savings than the users on the other four Los Angeles ramps. These differences may be explained by the longer delays experienced by drivers on the National and Vernon ramps (2.4 and 2.0 minutes vs. less than one minute on the other four Los Angeles ramps).

Drivers on the Guadalupe Expressway ramp in San Jose came closest to estimating the amount of time actually saved by using the carpool

Exhibit 5.9

ACTUAL AND PERCEIVED HOV LANE TIME SAVINGS



lane, reporting an 8.0 minute advantage, compared with the 7.8 minute delay measured in practice. This delay was the longest average delay experienced on any HOV project in the current study. Bay Bridge drivers who also experienced relatively long delays in the non-preferential toll plaza lanes, significantly overestimated the duration of this delay. Bay Bridge drivers estimated that 9.7 minutes could be saved daily by carpooling, while the actual savings ranged between 4 and 5 minutes.

Drivers on the three mainline projects also wildly over-estimated the time to be saved from using HOV lanes. A series of over 90 trial runs made during 18 different commute periods on Alameda 580, and over 80 trial runs made during 17 different commute periods on Marin 101 showed that traffic conditions were essentially free-flowing in the general traffic lanes of these freeways during the peak travel periods. Thus the time savings available to drivers using the carpool lanes were negligible most of the time. Yet drivers on these projects estimated the potential time savings to be 6.9 minutes on Alameda 580 and 6.6 minutes on Marin 101, undoubtedly reflecting upon the relatively small number of days when the freeway was not free-flowing and carpoolers realized significant savings. On the San Bernardino Busway the average time savings recorded by carpoolers driving the length of the project was seven minutes in the morning and five minutes in the evening. Drivers estimated the potential time savings to be 13.9 minutes.

One interpretation for the wide discrepancy between perceived time savings and actual time saved may be that differences tend to be amplified when one lane (i.e., the carpool lane) is moving while the other is not. In addition, the surveyed drivers may tend to cite the time savings available during the worst freeway congestion (or longest meter delay) that they remember. This tendency to perceive greater time savings in the carpool lane, however, undoubtedly makes the carpool lanes appear more attractive to drivers than to statisticians comparing raw numbers, and indicates that there may be a psychological advantage in providing a carpool lane even when the available time savings appear minimal. The illusion of greater time savings also helps to explain the relatively high violation rates observed on ramps in the face of negligible delays.

5.2 DRIVING RECORDS OF VIOLATORS AND NON-VIOLATORS

In an attempt to determine whether HOV lane violators also tend to ignore other traffic regulations, SYSTAN compared the overall driving records of HOV lane violators with those of non-violators, using data supplied by the CHP from a sampling of license plate numbers collected for survey purposes. The CHP, using a DMV data base, supplied anonymous records of violators and accident histories for a random sampling of registered owners of cars observed using HOV lanes illegally on the following twelve projects:

MAINLINE HOV LANES
Marin 101
Alameda 580
San Bernardino Busway

BRIDGE LANES
San Francisco/Oakland Bay Bridge

FWY TO FWY CONNECTORS
I-805 to San Diego Route 94
I-15 to San Diego Route 94

LOS ANGELES RAMP BYPASS LANES
Orangethorpe, OR 91
Woodman, LA101
National, LA10
Olympic/Pico, LA405
Vernon, LA11
Colorado, LA5

Driving records were also assembled for a random sampling of carpoolers and single drivers observed using the HOV projects and adjacent lanes legally. Early project reports (Reference 4) noted the following problems with the use of the anonymous driving records:

> "By the process of matching license plates to registered owners, one assumes that the driver is also the registered owner - which by no means is always the case. In a survey of accidents, the California State Auto Association found that only 50% of the drivers were also the registered owner. However, this percentage is presumably higher during weekday peak periods - the time in which the license plate numbers were collected. Moreover, the problem presumably affects both sample groups -- violators and non-violators -- equally, so that intergroup comparisons will not be adversely affected. Driving records are also 'incomplete' - erasure of conviction records occurs after 3 to 4 years, and the lag on incoming violation records is approximately 90 days."

With these caveats in mind, the data give some insights into the driving differences between violators and non-violators.

5.2.1 Comparisons for Mainline Lanes, Bridges, and Freeway Connectors

In comparing the driving records of violators and non-violators, it is instructive to consider two groups of projects: those mainline HOV lanes, bridges, and freeway-to-freeway connectors which carry drivers coming from a wide range of geographic areas; and the six sample Los Angeles on-ramps, each of which serves a more compact geographic area, and presumably, a more homogeneous driver population. Exhibit 5.10 tabulates the differences between the records of violators and non-violators using individual projects within these two groupings. In the case of the first groups of projects, HOV lane violators received more citations than non-violators on all six of the projects sampled, and this difference was statistically significant on five of the six projects. On the San Bernardino Freeway and on the I-15 interchange in

Exhibit 5.10

COMPARISON OF DRIVING RECORDS OF VIOLATORS VS. NON-VIOLATORS

MAINLINE HOV LANES	% of Drivers with no Adverse Record	Tickets per Driver	Convictions per Driver			Failure to Appear	Accidents per Driver
			Total	21655.5	All Other		
SAN BERNARDINO FREEWAY Violators (n = 80) Non-Violators (n = 115)	33% 41%	1.45* 0.70	1.78* 0.82	0.14 0.01	1.64* 0.81	0.15 0.03	0.26 0.20
MARIN 101 Violators (n = 72) Non-Violators (n = 91)	39%* 56%	1.08 0.59	1.32 0.75	0.01 0.0	1.31 0.75	0.06 0.04	0.24 0.22
ALAMEDA 580 Violators (n = 257) Non-Violators (n = 100)	46% 52%	1.08* 0.66	1.21* 0.72	0.03 0.0	1.18* 0.72	0.04 0.04	0.21 0.20
SAN FRANCISCO/ OAKLAND BAY BRIDGE Violators (n = 38) Non-Violators (n = 112)	24%* 46%	1.34* 0.68	1.53* 0.74	0.0 0.0	1.53* 0.74	0.16 0.08	0.22 0.21
SAN DIEGO RAMPS (I-805 — Rt. 94) Violators (n = 87) Non-Violators (n = 98)	39%* 58%	1.29* 0.69	1.56* 0.84	0.05 0.0	1.52* 0.84	0.03 0.0	0.18 0.17
(I-15 — Rt. 94) Violators (n = 55) Non-Violators (n = 105)	29%* 56%	1.67* 0.78	2.13* 1.05	0.0 0.01	2.13* 1.04	0.05 0.01	0.16 0.18
LOS ANGELES RAMPS							
ORANGETHORPE E/B (OR 91) Violators (n = 87) Non-Violators (n = 116)	41% 54%	1.20* 0.70	1.39 0.77	0.0 0.01	1.39 0.76	0.08 0.10	0.27 0.17
WOODMAN (LA 101) Violators (n = 95) Non-Violators (n = 118)	40%* 63%	0.78* 0.44	0.87* 0.50	0.0 0.01	0.87* 0.49	0.02 0.02	0.22 0.17
NATIONAL (LA 10) Violators (n = 91) Non-Violators (n = 121)	41% 38%	0.89 0.93	1.01 1.15	0.04 0.05	0.97 1.11	0.02 0.02	0.26 0.21
OLYMPIC/PICO (LA 405) Violators (n = 89) Non-Violators (n = 117)	44% 47%	0.72 0.85	0.80 0.99	0.01 0.01	0.79 0.98	0.0 0.02	0.21 0.22
VERNON (LA 11) Violators (n = 85) Non-Violators (n = 115)	52%* 35%	0.72 1.09	0.98 1.47	0.02 0.03	0.95 1.43	0.12 0.16	0.13* 0.36
COLORADO (LA 5) Violators (n = 26) Non-Violators (n = 128)	62% 52%	0.73 0.63	1.04 0.69	0.04 0.0	1.00 0.69	0.04 0.02	0.12 0.23

▨ * Indicates a statistically significant difference between violators and non-violators

San Diego, violators ignored other traffic regulations twice as often as non-violators, while on the I-805 interchange in San Diego, Alameda 580, Marin 101, and the San Francisco/Oakland Bay Bridge, they were cited between 64% and 97% more often than non-violators.

Because the number of tickets per driver is a statistic which can be skewed by a few drivers with a large number of tickets (several drivers sampled had amassed a dozen or more tickets in three years), a second statistic used in comparing violators and non-violators was the percentage of sampled drivers with no tickets at all. On each of the sample mainline HOV lanes and freeway-to-freeway connectors, the percentage of non-violators having no adverse record was larger than the corresponding percentage for HOV-lane violations (see Exhibit 5.10). Moreover the difference was statistically significant on four of the six projects sampled.

5.2.2 Comparisons for Ramp Bypass Lanes

The distinction between the driving records of violators and non-violators is not nearly so clear in the case of the Los Angeles ramp bypass lanes. Violators had more tickets per driver than non-violators on only three of the six ramps sampled, and the difference was statistically significant in only two of the six cases. On the Vernon Avenue ramp leading to the Harbor Freeway, moreover, the group of violators had a significantly higher percentage of drivers with no adverse records than the group of non-violators.

Most freeway on-ramps serve a narrowly circumscribed geographical area, and the population of drivers using a given ramp can be expected to be more homogenous than the population of drivers observed at any point along a freeway, on a major bridge, or moving from freeway to freeway. Those HOV projects serving a broader range of driver types from widely dispersed geographical areas tend to act as magnets attracting the violation-prone drivers from each area. As a result, a sampling of the population of violators on such projects reveals worse driving records than a like-sized sample of non-violators. This need not be the case for a single on-ramp serving a relatively homogenous population of drivers. Drivers who violate mainline HOV lanes must also be more resolute in their determination to ignore occupancy restrictions than ramp-bypass violators, since the mainline violator is generally exposed to the possibility of capture for longer periods of time. Violators observed on the mainline projects listed at the top of Exhibit 5.10 (mainline lanes, bridges, and freeway-to-freeway connectors) averaged 1.23 tickets per driver, well in excess of the average of 0.85 tickets per driver issued to violators observed on the six Los Angeles on-ramps listed at the bottom of the exhibit.

Only one of the twelve projects surveyed (the Vernon Ave. ramp on LA11) showed a significant difference between the accident history of violators and non-violators. In this case violators had safer driving records than non-violators. There were no significant differences in the accident records of drivers on different projects. Too few occupancy violation convictions (vehicle code 21655.5) appeared in the sample to support any statistical comparisons between the two groups of drivers. Of the 2398 driver records sampled, only 45 records of 21655.5 citations were found, an average of .02 citations per driver.

Subsequent analysis of the driving records of car owners observed using the six sample Los Angeles ramps revealed that, although there was little difference separating the records of violators and non-violators on any single ramp, the combined records of all drivers using each ramp correlate strongly with the ramp's violation rate. Exhibit 5.11 plots the ramp violation rate for six sample bypass lanes against the average number of tickets per driver computed from a representative sampling of over 200 drivers on each ramp. The graph shows a strong linear correlation (r = .88) between the number of tickets for all offenses amassed by each group of drivers and the violation rate experienced on each bypass lane.

It is hardly surprising to find a strong correlation between driving records and ramp violation rates. A new gasoline station in an area with a high crime rate is more likely to be robbed than a new station in a crime-free suburb. There is, however, a cautionary lesson for ramp designers and traffic managers embedded in this unsurprising finding: Ramp bypass lanes placed in areas with law-abiding drivers are likely to be less costly to enforce, and have a higher compliance rate, than lanes used by drivers with a long list of traffic infractions against their records.

5.3 PUBLIC INFORMATION

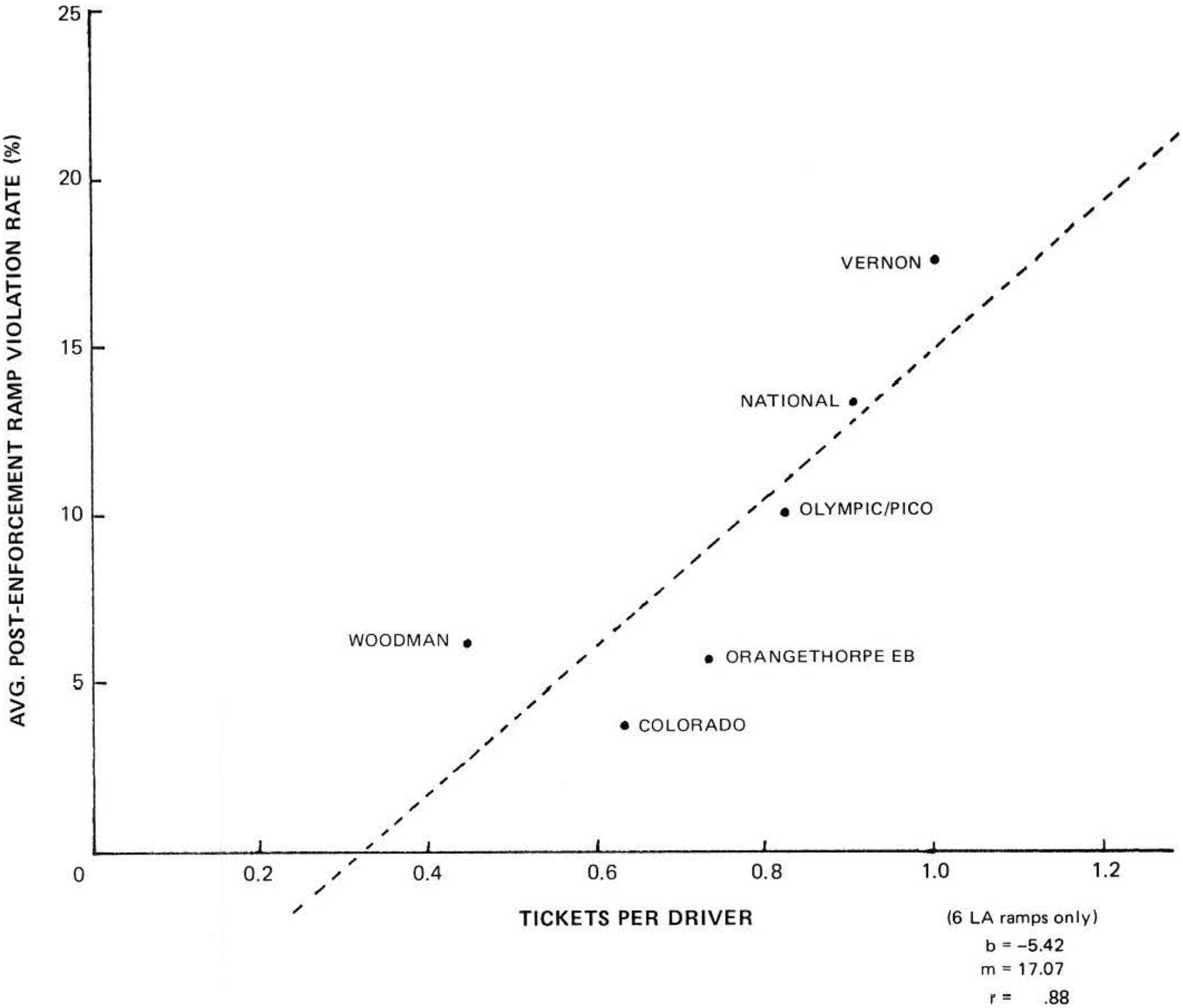
Public information regarding HOV lanes is disseminated through a variety of channels, including press releases, news reports, media campaigns, ramp and freeway handouts, driver education courses, public speeches, mailed brochures, freeway signs, and the driver's handbook published by the Department of Motor Vehicles. This subsection outlines general promotional approaches, catalogues media coverage, and documents the impact of a media campaign on ramp violation rates in San Diego.

5.3.1 General Approaches

Prior to the opening of new ramp meters and ramp bypass lanes, handouts are distributed at the ramps themselves to announce the intended opening date, explain the purpose of the project, and outline proper use of the new facility (see Exhibit 5.12). Press releases are provided to local newspapers, as well as to local agencies and officials. In addition to handouts, openings of major mainline HOV lanes have been preceded by extensive public information campaigns including television and radio announcements, newspaper advertisements, and freeway signs.

EXHIBIT 5.11

RAMP VIOLATION RATES VS TICKETS PER DRIVER



(6 LA ramps only)
b = -5.42
m = 17.07
r = .88

Exhibit 5.12
SAMPLE RAMP METERING HANDOUT

RAMP METERS AND CARPOOL LANES
SAVE YOUR TIME

This on-ramp, and others, will soon feature a metered signal light to help get you where you're going quicker. Some ramps will also have express carpool lanes. Please see the map on the other side for exact locations.

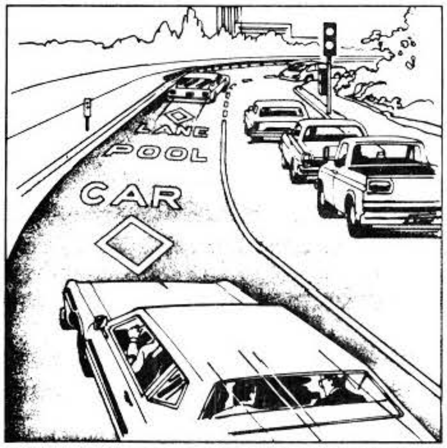
HERE'S WHY...

- Average freeway speeds have increased 13 miles per hour after metering, for a shorter commute time.
- With the addition of an express carpool lane, average "person delay" is reduced by 30%. This not only helps those who can rideshare, but also shortens the line for those who can't!
- Ramp meters and carpool lanes help control the flow of traffic onto the freeway, reducing stop-and-go conditions. As a result, accidents have been reduced by as much as 50%, and an estimated three million gallons of gas are saved each year.
- Savings in terms of personal time are estimated at $31 million a year!
- With a smoother freeway flow, overall air quality is improved.

HERE'S HOW...

Meters operate at peak traffic hours, when congestion is worst. There are only a few things to remember....

- Meters work like all red-green traffic signals.
- Usually, only one car per green is permitted.
- Express carpool lanes are only for vehicles with two or more persons.
- Since ramp instructions may vary slightly from location to location, each on-ramp has its own instruction sign.



This is a typical ramp meter with a carpool lane. Vehicles with one person wait on the metered side of the on-ramp, as cars ahead enter the freeway one by one, in response to green light signals. Vehicles with two or more people (only!) may move directly onto the freeway on the express carpool lane, marked with the federal diamond symbol which indicates "special use."

HELPFUL INFORMATION...

Ramp metering has been used successfully in Southern California for more than ten years, and studies show that meters *do* save time while reducing accidents. If a certain freeway appears to be moving freely when you're waiting to enter, it may mean that those lanes are already carrying capacity traffic, and that just a few more vehicles might cause considerable congestion. Freeways are "working" when traffic moves along smoothly.

This information has been prepared by Caltrans, as part of the Come Together program, a multi-agency effort to keep Southern California on the move.

For more complete information, send for a free copy of "Ramp Meters: Caltrans Answers the Hard Questions" from Come Together, PO Box 2304, Los Angeles, CA 90051. Or call (213) 620-3550.

Come Together

Urban areas throughout the state conduct on-going programs to promote carpooling. Commuter Computer in the Los Angeles area and RIDES in the San Francisco area function as carpool matching services, providing potential carpoolers with the names of others interested in carpooling that live and work in the same areas. State and local agencies have sponsored several programs describing the benefits of carpooling and the use of special carpool facilities.

5.3.2 Media Coverage

Media coverage of California's HOV projects has tended to be sporadic and generally negative. Newspaper articles on outraged drivers, threatened lawsuits, mannequin carpoolers, and other unflattering aspects of reserved lanes appear randomly and help to mold public opinion. While a limited amount of positive coverage has focused on a few projects, notably the San Bernardino Busway and the San Francisco/Oakland Bay Bridge Toll Plaza, this coverage is dwarfed by the negative barrage of publicity directed against such unpopular projects as the Santa Monica Diamond Lanes and the Alameda 580 project. Negative coverage has been particularly heavy during election years, when unpopular projects make easy political targets.

Ramp Metering and Bypass Lanes. Ramp meters and bypass lanes have received relatively little media coverage. Articles in local papers announce major metering projects as they are implemented, and generally include short explanations of the theory underlying the need for ramp control. Bypass lanes draw sporadic fire from columnists and editorial page letter-writers questioning their value and urging disobedience. Exhibit 5.13 contains a sampling of newspaper coverage of ramp meters and bypass lanes.

Mainline HOV Lanes. Mainline HOV lanes have drawn more media attention than all other forms of preferential treatment. Most of this attention has focused on two unpopular projects, the Santa Monica Freeway Diamond Lanes and the Alameda 580 corridor project. Relatively little attention has been directed toward the state's other mainline projects, the San Bernardino Busway and Marin 101. The San Bernardino Busway generally receives favorable, but infrequent press coverage. The Marin 101 lanes have received almost no attention in recent years, but a report on the project's early years (Reference 10) notes that media coverage was negative at the time of implementation.

SYSTAN's evaluation of the Santa Monica Freeway Diamond Lanes has thoroughly documented the scathing treatment that project received from the media (Reference 6). Although operations on the Santa Monica freeway improved somewhat after a disastrous opening day on March 15, 1976, when the newspapers carried banner headlines proclaiming "Freeway Chaos" media coverage grew steadily more hostile as the demonstration progressed. The diamond lanes operated amid much controversy for 21 weeks until August 9, 1976, when a U.S. District Court Order halted the demonstration. Hostile media coverage reflected, and was fueled by

Exhibit 5.13
SELECTED NEWSPAPER COVERAGE
Ramp Meters and Bypass Lanes

Reports Back Onramp Meters

Freeway Still Congested After Signals Installed

Grin and Bear It *By Lichty & Wagner*

12.26

© Field Enterprises, Inc., 1980

"Keep quiet, Ronald! I only brought you along so I could drive in the carpool lane!"

Motorists fume, but ramp meters are here to stay

By Mark Johnson
Staff Writer

There is nothing – absolutely nothing – more infuriating than breathing exhaust fumes, riding the clutch, jerking forward 10 feet and braking again, waiting for 15 cars in front to creep past a freeway ramp meter.

Meters Improve Traffic Flow

An Invitation to Civil Disobedience

There's one law I hate, and I totally refuse to obey it. Unless, of course, there's a police officer watching. Then I behave like the law-abiding citizen I usually am.

The law, however it's worded, has to do with those awful Diamond Lane metered on-ramps many of the freeways now have. The point of the on-ramps is to control the influx of cars onto the freeway and to blackmail commuters into carpooling. In case you haven't seen one, the metered ramp requires a lone driver to stop at a red light and allows car poolers to get on the freeway without stopping.

. . . .

Yes, I'm one of those, one of those all of you who obey this law hate. We whiz by you while you wait in a long line for your turn at the red light. I don't blame you. At first glance, it's almost like watching someone litter the highways. You get that wave of revulsion for someone who has no respect for the law.

It makes you rage, "They got no right," you say.

But I'm asking you to stop hating me and join me in an act of civil obedience against this futile, pointless and useless project. Just zip on by that dumb old red light. If enough of us do it, they'll have to change the law.

Just don't send me your tickets.

Traffic Tie-up

In its purported effort to save fuel, the State Department of Transportation (Caltrans) and the courts have perpetrated yet another outrage against the people of this city. I challenge those authorities to drive south on Bundy Drive in approaching the Santa Monica Freeway on-ramp (Pico Boulevard) at 7:45 a.m. on any work day. They will find long lines of cars on both sides to the ramp trying to merge into the right lane (designated for single occupants only), wasting gas and tying up traffic in the process, while the left lane of the ramp is virtually empty. The price for showing some common sense and using the left lane is $25.50.

The Philosophy of Metering

We noted a letter from a reader ("Traffic Tie-up," Letters, Dec. 22) concerning ramp metering at the Bundy on-ramp to the eastbound Santa Monica Freeway.

This letter raised two common concerns about ramp metering: (1) gasoline conservation and (2) backup on city streets.

We agree wholeheartedly that gasoline conservation should be considered whenever possible and sincerely believe that on-ramp metering is an approach to this.

While a short delay will be experienced at the on-ramp, by balancing the input to the freeway, the freeway will flow more smoothly, and thus the cars on it will be operating more efficiently and using less gasoline.

overwhelmingly negative public response to the Diamond Lanes. As Reference 6 notes, however:

> "Any attempt to lay the full blame for the hostile climate of public opinion on the media both oversimplifies and overstates the case. It is unlikely that the negative media reports alone could have generated such a hostile response if the reports were not reinforced by a negative impact on the lives of the public. In Los Angeles, the negative media image of the Diamond Lanes was reinforced daily for over 100,000 freeway users who found their daily commute trip lengthened by a project designed to benefit a perceptibly smaller proportion of the traveling public."

Since the demise of the Santa Monica Freeway Diamond Lanes, the Alameda 580 has assumed the unchallenged and unenvied role as the most controversial HOV project in California. The project itself was conceived in controversy, and the flames of the initial controversy flare up periodically, fanned by media coverage and political winds. The controversy began in 1975, when the Sierra Club, acting on citizen concern that the proposed widening of Interstate 580 would bring too much pollution and residential development, claimed that the environmental impact statement in support of the project was inadequate.

The Sierra Club threatened to bring suit against CALTRANS and other groups involved. In order to circumvent such legal action, especially since the time consumed would make it impossible to meet deadlines crucial to the continued funding of the construction, the state and federal transportation agencies bargained out-of-court with the Sierra Club. A resulting agreement stated that one lane in each direction would be open only to carpools and buses, while a second would be used as a buffer lane.

Since the agreement, many editorials have virulently denounced the HOV lanes, while others have staunchly upheld them. The controversy grew particularly heated during the 1980 election year, when construction was about to begin on an adjoining section of the freeway. In an advisory vote conducted as part of the November election Livermore residents voted 7,708 to 1,828 to direct their council to fight to remove the I-580 HOV lane restrictions. Exhibit 5.14 contains samples of selected newspaper coverage of California's mainline HOV lanes.

<u>Special Bridge Lanes</u>. Reserved lanes at bridge toll plazas have received relatively little press coverage and generated almost no controversy. Both the media and the public appear to accept the San Francisco/Oakland Bay Bridge lanes, and proposals to include special carpool lanes on other bridges in the San Francisco Bay Area (notably the San Mateo and Dumbarton Bridges) have met with little opposition. Exhibit 5.15 contains a few comments on special toll plaza lanes culled from Bay Area newspapers.

Exhibit 5.14

SELECTED NEWSPAPER COVERAGE

Mainline HOV Lanes

Growing controversy over freeway diamond lane

By Don Lattin

Diamond lanes—those bus and carpool corridors that sparked a commuter revolt in Southern California—have settled in as a source of daily aggravation in the far East Bay.

State studies ways to solve diamond lane dispute

By Stephen Malta

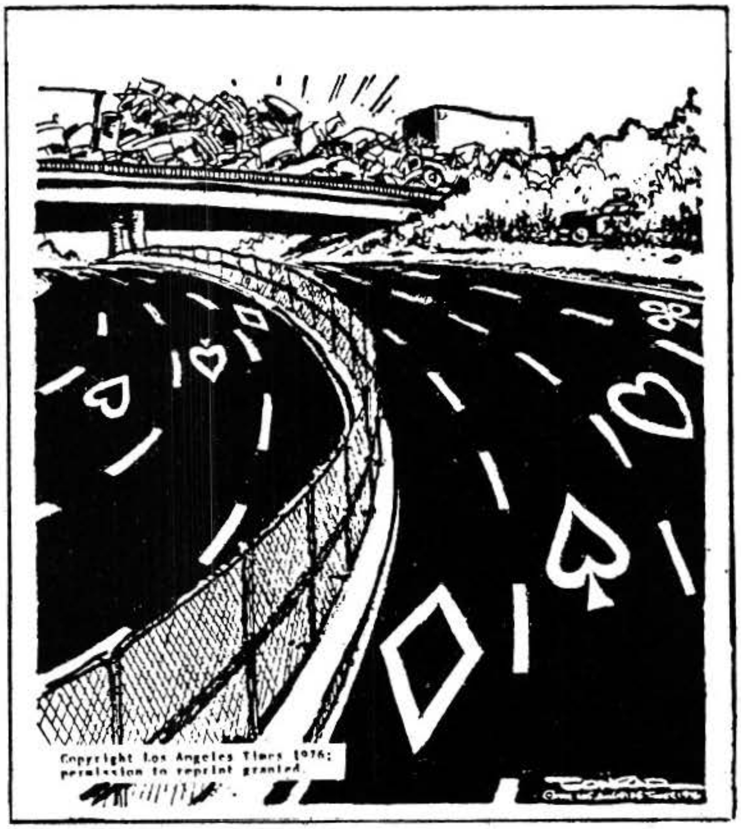
Staff writer

SACRAMENTO – In the wake of this week's fiery criticism of Interstate 580's car pool lanes, state transportation officials are considering a number of moves aimed at solving the "diamond lane" dilemma.

SAN BERNARDINO BUSWAY: GAMBLE THAT PAID OFF

At $61 million, the San Bernardino Freeway busway seemed like a costly gamble.

Instead, after several years of operation—and considering its initial cost, which is low at today's inflated figures—it has turned out to be a transportation bargain.



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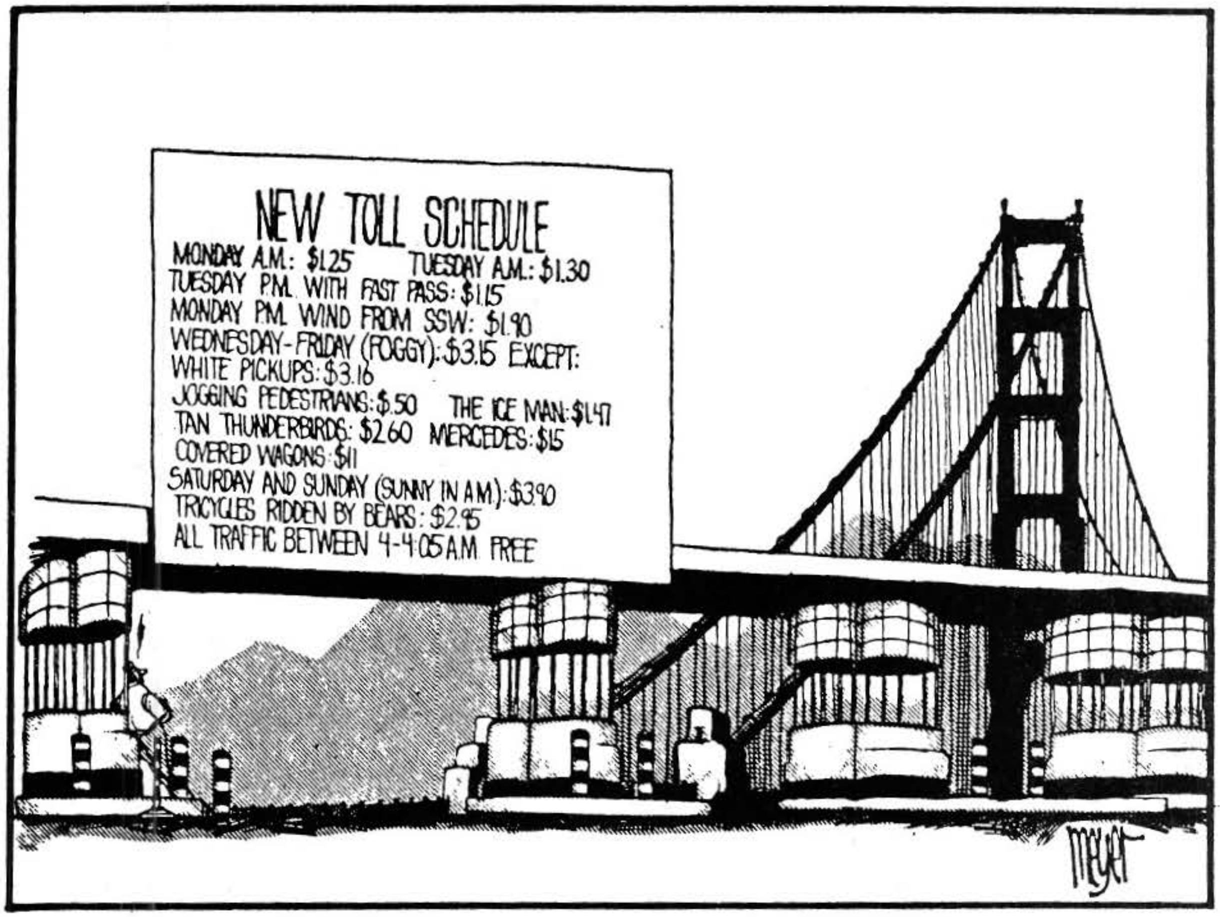
Highway Patrol causing hazards?

County makes detour maneuver in controversial I-580 issue

Exhibit 5.15
SELECTED NEWSPAPER COVERAGE
Toll Plaza Lanes



A pair of real dolls quickens the pulse of a Bay Bridge trip

This one's for all you Bay Bridge commuters who have the unmitigated gall to drive to San Francisco by yourselves.

How much longer do you think you can just sit there idling your gas-guzzling machine in the Toll Plaza traffic jam, mesmerized by the hypnotic rhythms coming from your stereo tape deck?

Don't you realize that every gallon of gas you waste only hastens the decline and fall of the American empire?

It's a well-known fact that you solo commuters will do anything you can to preserve the sanctity of the private automobile. Last year, for example, there was the Marin County mortician who claimed he qualified for the Golden Gate carpool lane because he carried three corpses in the back of his pick-up truck.

Having heard that some of you mono-commuters are planning even more subversive ways to sneak through the Bay Bridge carpool lanes, the caped commuter has been testing the defenses of Caltrans and the California Highway Patrol.

Armed with two armless (and legless) mannequins, a stunning brunette named Adriana and fiery redhead called Phantina, your faithful correspondent spent three days trying to get caught busting through the Bay Bridge barricades.

It's not easy getting caught. Believe me, we tried.

No one (especially Adrianna) batted an eyelash when Phantina's wig slipped off, revealing a shiny and slightly scratched scalp.

Review Highlights

Carpool lanes on the Oakland-San Francisco Bay Bridge provide free and speedier passage on weekdays between 6 and 9 a.m. Between 1972 and 1975, commuters paid a token monthly fee to use the carpool lanes. Since the $11 million BART tube was paid off six years ago, and Caltrans could legally allow free passage for carpoolers, use of the two center lanes has been steadily increasing. An effective way to encourage East Bay residents to share rides, the lanes can cut commute time between five and fifteen minutes a day.

Coverage and Violations. Negative media coverage and public hostility have tended to focus on individual projects, rather than the concept of preferential lanes. In Los Angeles, the Santa Monica Freeway Diamond Lanes were mauled by the media, while the San Bernardino Busway, a short distance east on the same Interstate route, has generally been treated fairly and favorably. In the San Francisco Bay Area, Alameda 580 receives predominantly negative press coverage, while Marin 101 goes virtually unnoticed and the Bay Bridge toll plaza lanes receive moderately favorable coverage. While it is impossible to quantify the impact of media coverage and public attitudes on violation rates, it is worth noting that the two California HOV projects receiving the most favorable press notices, the San Bernardino Busway and the San Francisco/Oakland Bay Bridge, have the lowest lane violation rates of all the projects included in this study. On the other hand, if media popularity were the sole criteria governing HOV lane compliance, the Santa Monica Diamond Lanes would have been packed bumper-to-bumper with violators. As it was, lane violation rates on this manifestly unpopular project fluctuated between 10% and 20%, well below the levels recorded on ramp bypass lanes, Marin 101, and Alameda 580.

5.3.3 Impact of Public Information on Violations

In an attempt to gain additional insights into the impact of public information on violations, violation rates on San Diego's ramp bypass lanes were monitored before, during, and after a media campaign focusing on the use and abuses of bypass lanes.

The media campaign consisted of a series of public service radio and TV ads explaining the reasons underlying the bypass lanes, describing their proper use and warning against their illegal use. The campaign was carried on local radio and TV stations in San Diego during August and September, 1981.[3] During the first month of the campaign, enforcement on San Diego ramps was limited to routine activities. During the second month, special enforcement was scheduled on the ramps in the El Cajon CHP Area.

The table below summarizes the violation rates on representative San Diego bypass lanes prior to the campaign and during the two months of the public relations campaign.

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[3] The announcements were aired 64 times in the two months by local TV stations, but only one airing was during prime time. Radio stations broadcast prepared spot announcements 186 times during the two-month campaign (between four and five times a day), often during peak commute hours.

SAN DIEGO RAMP VIOLATION RATES
Before and During Radio and TV Campaign

	Before Campaign	**First Campaign Month**		**Second Campaign Month**			
	(After Third Enforcement Wave)	(Before Special Enforcement)		(Ramps without Special Enforcement)		(Ramps with Special Enforcement)	
RAMP	**(RVR)**	**(RVR)**	**(% Change)**	**(RVR)**	**(% Change)**	**(RVR)**	**(% Change)**
I-805 — SD94	2.3	4.9	+76.3%	4.8	+17.1%		
I-15 — SD94	2.9	3.5	+20.6%	3.9	+11.4%		
Waring — I-8	2.3	2.2	−2.9%	na	na		
SD94 — SD94	0.9	1.0	+11.4%			0.4	−55.4%
El Cajon — I-8	1.5*	2.3	+54.0%			0.8	−65.9%
Overall Average	1.8	2.7	+50.0%	4.5	+15,3%	0.6	−63.6%

As can be seen, the first month of the Radio and TV campaign had no impact in reducing the already low violation rates in the San Diego area. During the second month of the campaign, violation rates dropped significantly on the ramps in the El Cajon area which received special enforcement, and increased slightly on those ramps which received no special enforcement. Although the addition of special enforcement caused violations to drop appreciably, the public information campaign alone had no impact on violations. While effective public information programs are essential at the time a project is introduced, and may increase public acceptance during the project's life, there is no evidence to date that they are able to affect violation rates on on-going projects.

5.4 ADDITIONAL INSIGHTS

5.4.1 Impact of Educational Handouts

In a study conducted by CALTRANS in late 1976, educational handouts were distributed on several ramp meter bypasses on the northbound Harbor Freeway in the hope of ameliorating the problem of increasing violation rates. At the same time, the CHP increased enforcement levels in the area. A study of the impacts of the handouts (Reference 25) noted that the handouts did not seem to affect violation rates. However, changes in enforcement levels at certain ramps were not monitored carefully, so that the combined impacts of handouts and enforcement on violation rates could not be assessed.

5.4.2 Driver Excuses

In 1977, CALTRANS distributed short surveys to all vehicles using the bypass lanes at 22 ramps on Routes 5, 10, and 11 in Los Angeles. Two separate surveys were handed out depending on whether the vehicle was legitamately using or violating the bypass lane. Violators were asked why they were using the carpool lane. A CALTRANS memorandum (Reference 8) summarized the reasons given by the violator:

1. They do not believe it is within CALTRAN's right to discriminate against the single driver (53%);
2. They do not believe in ramp metering and find this a convenient way to beat it (35%);
3. They were ignorant of the fact that they are breaking the law (32%);
4. They were in a hurry and did not expect to get caught (25%);
5. They see others doing it and feel foolish sitting in the line (14%); and
6. They thought the Diamond Lane Demonstration was over (14%).

In a less extensive, informal sampling of violators, officers assigned to special enforcement in the San Diego area in mid-1980 recorded the excuses offered (or not offered) by apprehended violators during the early months of the current study. The following breakdown ranks the excuses given by 71 violators over an eight-day period:

	Number	(%)
No comment	17	24%
Late	12	17%
Didn't understand law	11	15%
Didn't see signs	6	8%
Admitted violation	5	7%
Didn't think law applied to motorcycles (empty taxis)	4	6%
Lost (confused)	3	4%
Forced into lane	3	4%
Everyone else was doing it	2	3%
New to area	2	3%
Miscellaneous (no two alike)	6	8%
	71	100%

The reasons volunteered to officers by apprehended violators differ in many respects from those checked off on the survey form distributed by CALTRANS in the earlier study. Two excuses rank relatively high on both lists: "I was late," and "I didn't understand the law." Officers interviewed said that they tended to discount the latter excuse in many instances. In any case, the overall percentage of violators pleading ignorance of the law was relatively low (15% of the apprehended violators) in the later, informal survey, suggesting that existing public information and enforcement programs have at least made non-carpoolers aware of the illegality of using the lanes.

5.4.3 Incidence of Repeat Violations

Prior to the first wave of the special enforcement activities, license plates of violators on all mainline HOV lines, six Los Angeles ramps, and two San Diego ramps were recorded on three separate days, both to provide a sample population for survey mailings and to gauge the incidence of repeaters among the violator population. Following the third enforcement wave, license plates of violators were again recorded on three separate days for the same purposes.

Repeat Violations over a Three-Day Period. A comparison of violation rates on the sample projects over the two three-day periods suggests that the incidence of repeat violators is relatively low. Exhibit 5.16 tabulates the percentage of repeat violations (formed by dividing the number of violations attributable to repeaters, Vr, by the total number of violations, Vt, observed over each three-day span), as well as an estimate of the probability that a known violator will violate on any particular day.[4]

The average repeat violation percentage recorded prior to special enforcement was a relatively low 13.3%, while the average recorded after the third wave of enforcement was 12.1%. These percentages correspond to probabilities of .07 and .06, respectively, that a known violator will violate on any given day. The highest repeat violation percentage during the two sampling periods was 28.6% (corresponding to a .16 probability of repeating), recorded after the third wave of special enforcement on the Vernon Avenue ramp leading to the Harbor Freeway. Although this ramp also had a relatively high violation rate, there appeared to be little correlation between the violation rate on a project and the incidence of repeat violations.

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[4] Because the ratio Vr/Vt is dependent on the number of days violations were counted, an attempt was made to express this ratio in terms of the probability that a known violator will violate on any particular day. If it is assumed that the probability of violating is independent of other violations (not a particularly good assumption, but one that turns out to be mathematically tractable) it can be shown that, for a three-day sample,

$$P = 1 - \sqrt{1 - Vr/Vt},$$

when P represents the probaiblity that a known violator will choose to violate on any given day. Values of this probability are tabulated in Exhibit 5.16.

Exhibit 5.16

INCIDENCE OF REPEAT VIOLATIONS
Over a Three-day Observation Period

		Repeat Violation Percentage		Violation Probability	
PROJECT		**1980**	**1981**	**1980**	**1981**
MAINLINE HOV LANES					
Marin 101		5.3	0.0	.027	.0
Alameda 580		2.8	4.9	.014	.025
San Bernardino Busway		12.8	NA	.066	NA
SF/OAKLAND BAY BRIDGE		13.5	4.8	.070	.025
LOS ANGELES BYPASS RAMPS					
National	LA 10	23.7	26.7	.127	.144
Vernon	LA 11	23.7	28.6	.127	.155
Orangethorpe	OR 91	6.4	4.8	.032	.024
Woodman	LA 101	15.0	10.2	.078	.052
Olympic/Pico	LA 405	10.2	4.6	.052	.023
Colorado	LA 5	3.0	8.4	.015	.043
FWY-FWY CONNECTORS					
I 805-SD 94		25.5	NA	.137	NA
I 15-SD 94		17.4	NA	.091	NA
ALL PROJECTS		13.3	12.1	.069	.062

$$\text{Repeat Violation Percentage} = \frac{\text{Violations by repeaters}}{\text{Total violations}} \times 100\% = \frac{V_r}{V_t} \times 100\%$$

$$\text{Violation Probability} = 1 - \sqrt{1 - \frac{V_r}{V_t}}$$

Year-to-Year Changes. Although violation rates on the sample projects dropped appreciably over the first year of special enforcement, the incidence of repeat violations did not change appreciably between 1980 and 1981. The average percentage of repeat violations over comparable projects dropped by only 9% (a 1.2% change), and a statistically significant change was recorded on only one sample ramp, Olympic/Pico on the San Diego Freeway, where the repeat violation percentage dropped from 10.2% to 4.6%, and on Marin 101, where no repeat violators were observed during the post-enforcement phase.

Exhibit 5.17 tabulates the number of individual violators sighted during both the pre-enforcement and post-enforcement observations on Los Angeles ramps. In 1981, 88 repeat violators (averaging 2.3 violations each), and 1,095 one-time-only violators accounted for 1,296 violations over the three-day observation period. Of the 1,184 violators seen in 1981, 28 had been seen in 1980. This, compared to 89 repeaters within 1981, indicates that while the repeat rate across years was lower than the repeat rate across days, it was still substantially above zero. That is, some confirmed violators continued to disobey the occupancy restrictions even after being exposed to a full year of special enforcement activities.

Inference. While the results of a limited three-day observation period cannot be conclusive, the low incidence of repeat violations indicates that HOV lane violation rates tend to reflect the actions of a large number of drivers transgressing at infrequent intervals, rather than the day-to-day actions of a small group of repeaters. This indication is supported by the responses to numerous survey questions, which suggest that observed violators are not markedly different from ordinary drivers (see Section 5.1.1). There are, however, a small hardcore of repeat violators on certain projects who managed to remain undaunted by the first year of special enforcement.

5.5 SUMMARY OF KEY FINDINGS

5.5.1 Driver Attitudes

Surveys mailed to a sample of single drivers, carpoolers, and carpool lane violators on 13 sample projects before and after special enforcement activities led to the following conclusions regarding driver attitudes.

General Attitudes:

- Although the differences between violators, carpoolers and general users on a particular project are few and generally predictable, there are major differences separating the attitudes and perceptions of users of individual projects. This was especially true on the mainline HOV lanes, with all classes of drivers on the controversial Alameda 580 project viewing the preferential lanes unfavorably, while drivers using Marin 101, the San

Exhibit 5.17

REPEAT VIOLATION SUMMARY

Ramp Location		Violations Sighted		Repeat Violators Sighted			Violations by Repeat Violators		Repeat Violation Percentage	
		1980	1981	1980	1981	Common in Both Years	1980	1981	1980	1981
National	LA10	443	262	50	28	10	105	70	23.7	26.7
Vernon	LA11	481	276	52	36	10	114	79	23.7	28.6
Orangethorpe	OR91	188	42	6	1	2	12	2	6.4	4.8
Woodman	LA101	353	206	25	10	3	55	21	15.0	10.2
Olympic/Pico	LA405	964	415	47	9	3	98	19	10.2	4.6
Colorado	LA5	67	95	1	4	0	2	8	3.0	8.4
Total		2,496	1,296	181	88	28	384	199	15.4	15.4

Francisco/Oakland Bay Bridge, and the San Bernardino Busway were generally more tolerant of HOV projects -- relatively few drivers on these two projects opposed the idea of more freeway lanes for carpools. Among the users of ramp bypass lanes, San Diego drivers viewed the idea of dedicated freeway lanes more favorably than Los Angeles drivers. Some of the Los Angeles opposition seemed to reflect the much-publicized controversy surrounding the ill-fated Santa Monica Freeway Diamond Lanes in 1976.

Perceptions of Enforcement:

- Drivers are significantly more aware of in-place, in-view enforcement than of enforcement requiring pursuit and ticketing on freeway shoulders. This distinction was particularly evident before special enforcement activities were initiated. On the San Bernardino Busway, where violators are usually apprehended and ticketed in the buffer lane in full view of passing motorists, only 13% of all respondents said they had never seen the CHP ticketing violators. On Marin 101, however, where the CHP must escort violators to the side of the freeway before issuing tickets, 22% of all respondents reported that they had never seen an occupancy citation issued. On one San Diego ramp with an ample refuge area where CHP officers could stand and wave over violators in full view of other drivers, 25% of all respondents reported they had never seen a citation issued for illegal use of the carpool lane. On a nearby ramp with a scanty refuge area that forces officers to pursue violators and issue tickets some distance from the ramp itself, the corresponding percentage was 70%.

- Although special enforcement activities significantly improved driver awareness of enforcement on the surveyed projects, a surprisingly high percentage of drivers using ramps with bypass lanes remained oblivious to the presence of enforcement. After three waves of special enforcement, between 15% and 45% of the drivers on the sample ramps reported that they had never seen a driver ticketed for using the bypass lanes illegally. Over two-thirds of all drivers surveyed felt that enforcement levels "stayed about the same" during the year of special enforcement.

- Drivers themselves perceive a need for more enforcement. Only about 10% of the drivers interviewed prior to the first wave of enforcement felt that current enforcement levels were sufficient. This was uniformly true on all projects except Alameda 580, where 33% of the respondents felt that there was no need for the CHP to enforce more often.

Perceptions of Violations:

- Drivers tended to overestimate low violation rates and underestimate high violation rates. While drivers appeared to be sensitive to major improvements in the violation picture, they are not likely to detect changes in the range below a 25% lane violation rate (or a 6.5% ramp violation rate).

- Most drivers feel that HOV lane violations are a minor problem. Drivers on the San Bernardino Busway and Guadalupe Expressway felt that violations represented a more serious problem, while Alameda 580 drivers were less concerned than other drivers about the presence of violators. Forty-three percent of the Alameda 580 respondents felt that violations were no problem whatsoever, presumably reflecting the adverse media publicity and public hostility directed toward that project.

Perceptions of Ramp Metering:

- Ramp users have mixed feelings regarding the benefits of ramp metering. While over two-thirds of all drivers feel that metering has improved freeway flow, under 21% feel that it has shortened their individual trip time.

Perceived Time Savings:

- Violators, carpoolers, and general drivers alike greatly over-estimate the average time savings afforded by HOV lanes. This tendency to perceive greater time savings in the carpool lane undoubtedly makes the carpool lanes appear more attractive to drivers than to statisticians comparing raw numbers, and indicates that there may be a psychological advantage in providing a carpool lane even when the available time savings appear minimal. The illusion of greater time savings also helps to explain the relatively high violation rates observed on ramps in the face of negligible delays.

5.5.2 Driving Records

- HOV lane violators are likely to have poorer overall driving records than non-violators. An examination of driver records on mainline freeway lanes, bridges, and other HOV projects serving drivers from a wide range of geographic areas showed that HOV lane violators on these projects had significantly worse driving records than non-violators. On ramp-bypass lanes serving narrowly circumscribed geographic areas, however, few differences were found between the driving records of violators and non-violators using a particular ramp. Nonetheless, comparisons among different ramps showed a strong correlation between the records of all drivers using the ramp and the ramp violation rate: the worse the driving records, the higher the ramp violation rate.

5.5.3 Media Coverage

- Media coverage of California's HOV projects has tended to be sporadic and generally negative. Negative coverage has peaked during election years and has tended to focus on individual projects, rather than the concept of preferential lanes. In Los Angeles, the Santa Monica Freeway Diamond Lanes were mauled by the media, while the San Bernardino Busway further east on the same Interstate route has generally been treated fairly and favorably. In the San Francisco Bay Area, Alameda 580 is the focus of predominantly negative press coverage and hostile public opinion, while Marin 101 goes virtually unnoticed, and the Bay Bridge toll plaza receives moderately favorable coverage.

5.5.4 Repeat Violations

- The incidence of repeat violations over short periods is relatively low, suggesting that HOV lane violation rates tend to reflect the actions of a large number of drivers transgressing at infrequent intervals, rather than the day-to-day actions of a small group of repeaters. There are, however, a small group of persistent repeaters on certain projects who managed to remain undaunted by the first year of special enforcement.

6. TOWARD FUTURE ENFORCEMENT PROGRAMS

This section outlines future enforcement programs for California's ramp meter bypass lanes and mainline HOV projects. The costs of these projects are tabulated and weighed against the benefits accruing from increased compliance with HOV restrictions. The proposed programs are based on the assumption that sufficient enforcement resources will be available.

6.1 RAMP METER BYPASS LANES

The effectiveness of the various enforcement strategies tested in the current study is summarized in matrix form in Exhibit 6.1. Routine enforcement efforts were difficult to direct and proved ineffective against ramps with medium and high violation rates. Heavier levels of special enforcement almost always reduced violation rates appreciably when ramp violation rates exceeded 6.5% at the outset of the enforcement effort. When violation rates were below this level, however, special enforcement efforts often failed to reduce violation rates further.

6.1.1 Proposed Program

Since the effectiveness of special ramp enforcement activities depends on existing violation levels, these levels should be monitored periodically in developing future enforcement programs. On the basis of the results obtained during the current study, the following program should prove effective in reducing and controlling violations on ramp meter bypass lanes:

1. Monitoring

   CALTRANS shall monitor violation rates on each metered ramp bypass lane annually. Ramp violation rates will be calculated and supplied to CHP Division Headquarters.

2. Targeting

   The CHP will be responsible for providing special enforcement in a periodic but random pattern, with special enforcement levels reflecting monitored violation rates as follows:

Exhibit 6.1

MONTH BY MONTH IMPACTS OF DIFFERENT ENFORCEMENT LEVELS ON RAMP VIOLATION RATES

HIGH VIOLATION RAMPS Enforcement		Change in Ramp Violation Rates					
		Decrease		No Change	Increase		
Officer Hours per Month	(level)	>20%	6-20%	±5%	>20%	6-20%	Total Observations
0	(none)	1 (33%)		1 (33%)	1 (33%)		3 (100%)
0-1	(routine)	2 (20%)	2 (20%)	1 (10%)	3 (30%)	1 (20%)	10 (100%)
1-5	(mandated routine)	1 (7%)	4 (27%)	5 (33%)	1 (7%)	4 (27%)	15 (100%)
5-10	(1 C, ½ D/wk)	2 (25%)	1 (13%)	3 (38%)	2 (25%)		8 (100%)
10-15	(1 C, 1 D/wk)	2 (67%)				1 (33%)	3 (100%)
15-25	(1 C, 2 D/wk)	6 (75%)		1 (13%)	1 (13%)		8 (100%)
25-50	(1 C, 4 D/wk)	8 (80%)	1 (10%)			1 (10%)	10 (100%)
Total		22 (39%)	8 (14%)	11 (19%)	9 (16%)	7 (12%)	57 (100%)
MEDIUM VIOLATION RAMPS							
0	(none)	2 (13%)	2 (13%)	3 (20%)	4 (27%)	4 (27%)	15 (100%)
0-1	(routine)	4 (25%)	2 (13%)	1 (6%)	3 (19%)	6 (38%)	16 (100%)
1-5	(mandated routine)	3 (38%)	2 (25%)	1 (13%)	2 (25%)		8 (100%)
5-10	(1 C, ½ D/wk)	1 (50%)	1 (50%)				2 (100%)
10-15	(1 C, 1 D/wk)	5 (46%)	3 (27%)	2 (18%)	1 (9%)		11 (100%)
15-25	(1 C, 2 D/wk)	5 (38%)	3 (23%)	2 (15%)	2 (15%)	1 (8%)	13 (100%)
25-50	(1 C, 4 D/wk)	5 (50%)	2 (20%)	1 (10%)	1 (10%)	1 (10%)	10 (100%)
Total		25 (33%)	15 (20%)	10 (13%)	13 (17%)	12 (16%)	75 (100%)
LOW VIOLATION RAMPS							
0	(none)	15 (35%)	3 (2%)	5 (12%)	8 (19%)	12 (28%)	43 (100%)
0-1	(routine)	3 (15%)	8 (40%)	2 (10%)	3 (15%)	4 (20%)	20 (100%)
1-5	(mandated routine)	1 (17%)	1 (17%)	2 (33%)		2 (33%)	6 (100%)
5-10	(1 C, ½ D/wk)	5 (33%)	1 (13%)	2 (18%)		3 (33%)	11 (100%)
10-15	(1C, 1 D/wk)	5 (23%)	7 (32%)	3 (14%)	4 (19%)	3 (14%)	22 (100%)
15-25	(1 C, 2 D/wk)	6 (35%)	3 (18%)	2 (12%)	3 (18%)	3 (18%)	17 (100%)
25-50	(1 C, 4 D/wk)	1 (25%)	1 (25%)	1 (25%)	1 (25%)		4 (100%)
Total		36 (29%)	24 (20%)	17 (14%)	19 (15%)	27 (22%)	123 (100%)

Key n (%) — Number of observations; Percent of row total

▨ Indicates enforcement levels producing a decrease in violation rates for the majority of the cases observed.

a) Low Violation Ramps (0 to 6.5%) RVR):

Frequency: Once yearly

Level:

- One officer, 1 day per week for four weeks; or
- Two officers, 2 days per week for one week.

b) Medium Violation Ramps (6.5% to 12% RVR):

Frequency: twice yearly

Level:

- One officer, 1 day per week for four weeks; or
- Two officers, 2 days per week for one week; or
- One officer, 2 days per week for four weeks; or
- Two officers, 1 day per week for four weeks.

c) High Violation Ramps (over 12% RVR):

Frequency: twice yearly

Level:

- One officer, 2 days per week for four weeks; or
- Two officers, 1 day per week for four weeks; or
- One officer, 4 days per week for four weeks; or
- Two officers, 2 days per week for four weeks.

d) Newly Opened Bypass Lanes:

Newly opened bypass lanes should be enforced at level (b) or (c) above on a semi-annual basis beginning with the first month after opening. Within the first year of operation, violation rates will be measured and the ramp will be classified for future enforcement efforts.

3. Scheduling

CHP Areas will be responsible for scheduling enforcement on targeted ramps within their jurisdictions.

Approximately twenty weeks of routine enforcement should intervene between successive periods of special enforcement on each ramp.

To provide a point of contact within Division Headquarters, and to pave the way for continuing cooperation between CALTRANS and the CHP, it is recommended that the Coordinating Committee established during this study assume a permanent stature within the two organizations. This Committee consists of one representative from each of the three CHP Divisions (Golden Gate, Southern, and Border Divisions) having major TSM enforcement responsibilities, as well as one CALTRANS representative from the corresponding geographic areas (representing CALTRANS Districts 04, 07, and 11). The Committee is chaired by a CHP representative from the Patrol's Sacramento Headquarters.

As the enforcement program outlined above is initiated, special enforcement activities within each CHP Area will resemble those carried out during the current study. Individual areas will focus enforcement attention on all ramp bypass lanes within their jurisdictions, instead of just those sample ramps included in the study, and special enforcement schedules may be spread over the calendar year instead of being concentrated in one month during each quarter. As the program progresses, it is anticipated that more and more ramps will be shifted into the "low violation" category, and, consequently, will require minimum levels of special enforcement. At the outset of the current study 10 of 60 sample ramps (16.6%) fell into the "low violation" category. By the study's end, however, 55% of all study ramps had violation rates under 6.5%. Thus the proposed program is designed to become cheaper to operate as time goes on and existing violation levels are reduced.

6.1.2 Program Cost

Special Enforcement. Officers assigned to special ramp enforcement duties are typically outside their vehicles and in the process of apprehending or ticketing violators during most of the peak commuting period. These duties cannot be combined effectively with other mainline patrol activities, and most supervising sergeants consider patrol officers to be unavailable for other duties when they are assigned to ramp enforcement. It is appropriate, therefore, that the full cost of the time of the special enforcement officer be charged to ramp enforcement when estimating the cost of the enforcement program.

Dedicated ramp enforcement will be required, at most, during four hours of the morning peak period and four hours of the evening peak. Since it is difficult for a single officer to cover both of these peaks, CHP Command Areas must meet the additional personnel needs imposed by ramp enforcement requirements by increasing personnel levels during two separate shifts. This may be accomplished in either of two ways:

1. By offering overtime duty to existing personnel; or

2. By adding personnel to the morning and evening shifts.[1]

In the first case, existing officers must be paid an overtime premium. In the second case, new officers must be hired for eight hours per day to accomplish duties which consume, at most, four hours. While the newly hired officers are available for other duties during the remaining hours of their shift, they will be dedicated to ramp enforcement during the peak commuting hours when patrol officers are most needed. Accordingly, their full salary will be charged to ramp enforcement in computing the cost of the ramp enforcement program.

The two approaches to meeting ramp staffing requirements cited above have markedly different cost implications. Exhibit 6.2 summarizes the cost of the proposed program of special enforcement under the two different staffing options. In computing the cost of overtime enforcement, a salary of $19.08 per hour was assumed, along with a cost of 29 cents per mile for a patrol vehicle. This salary represents the overtime rate for a top-step officer and includes no allowance for fringe benefits or administrative costs, which have been accounted for in the officer's basic salary. In computing the cost of adding personnel for ramp enforcement, an annual cost of $38,283 per officer was assumed. This represents the $34,142 budgeted annual cost of a first year officer (salary + fringe benefits), along with a 29 cents per mile allowance for patrol car use.[2]

Routine Enforcement. Under the proposed program, routine enforcement of ramp meter bypass lanes would continue as in the past. The effectiveness of this enforcement would be increased by the concurrent program of special enforcement (see Section 2.1.4). As in the case of special enforcement, routine enforcement activities will vary with the ramp violation rate. In the case of routine enforcement, however, the variation will reflect citation opportunities rather than a programmed level of enforcement. The table below lists the average levels of routine enforcement recorded prior to the initiation of special enforcement activities on ramps with low, medium, and high violation rates and assigns an annual cost to this enforcement activity.

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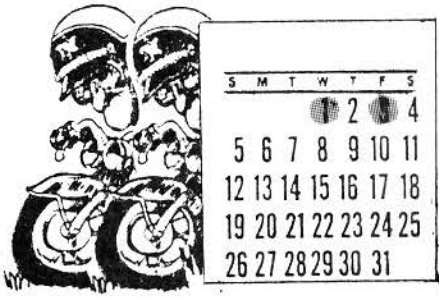
[1] It is, of course possible to assign an existing officer to ramp duty without either adding personnel or offering the inducement of overtime. In this case, however, the officer would be removed from higher priority duties during the peak hours of traffic flow, and the cost of covering these duties would have to be borne somehow. Thus, the cost consequences would be the same as those incurred under option (1) or (2), except in the unlikely case in which an area had surplus officers available during the peak commuting periods.

[2] CHP salary information was obtained from a series of phone calls and memoranda exchanged with John Keller and Mike Maples of the CHP's Long Range Planning Section.

Exhibit 6.2

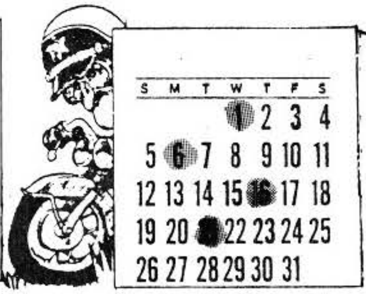
COST PER RAMP OF BYPASS LANE ENFORCEMENT PROGRAM

Annual Enforcement Time per Ramp	Annual Cost per Ramp		
Hours/Year	Staffing	Option	
	Overtime	New Personnel	
16	$ 371	$ 598	Low Ramps
32	$ 742	$1,196	Medium Ramps
64	$1,484	$2,393	
128	$2,968	$4,785	High Ramps

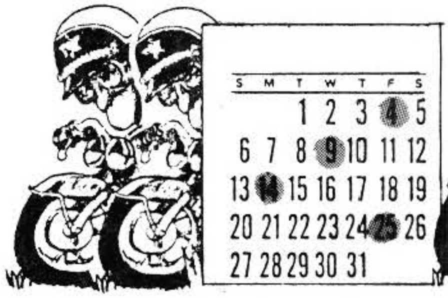


TWO OFFICERS
TWO DAYS PER WEEK
FOR ONE WEEK

OR

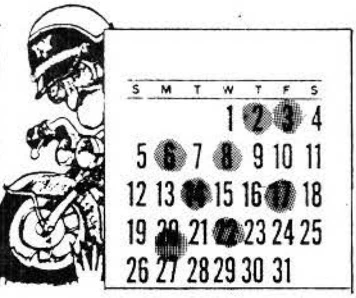


ONE OFFICER
ONE DAY PER WEEK
FOR FOUR WEEKS

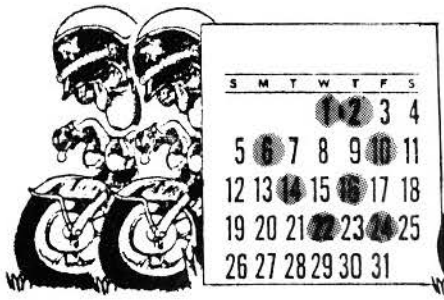


TWO OFFICERS
ONE DAY PER WEEK
FOR FOUR WEEKS

OR

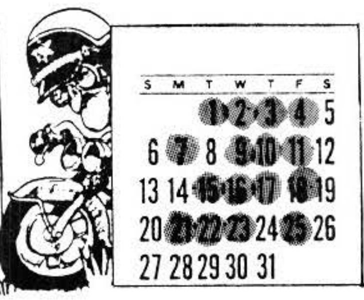


ONE OFFICER
TWO DAYS PER WEEK
FOR FOUR WEEKS



TWO OFFICERS
TWO DAYS PER WEEK
FOR FOUR WEEKS

OR



ONE OFFICER
FOUR DAYS PER WEEK
FOR FOUR WEEKS

ROUTINE ENFORCEMENT COST ESTIMATES
(Baseline Data)

RAMP VIOLATION RATE	CITATIONS/RAMP/DAY	HOURS/YEAR	COST/YEAR
Low (<6.5%)	0.14	5.88	$131
Medium	0.17	7.14	$160
High (>12%)	1.15	48.30	$1080

The annual routine enforcement costs listed above have been estimated by assuming that each routine citation requires 10 minutes of officer time, computing the amount of time devoted to these activities annually, and prorating the annual salary, benefits, and vehicle costs budgeted for a top-step traffic officer over this amount of time. This cost allocation procedure differs from that involved in assessing the cost of special enforcement, and reflects the fact that routine ramp enforcement duties are conducted in concert with the other duties undertaken by patrol officers.

Total Enforcement Costs. The table below shows the combined costs of special and routine enforcement on ramp meter bypass lanes with low, medium and high violation rates.

TOTAL ENFORCEMENT COST ESTIMATES
(Dollars/ramp year)

RAMP	ROUTINE	SPECIAL ENFORCEMENT		TOTAL	
VIOLATION RATE	ENFORCEMENT	Overtime	New Personnel	Overtime	New Personnel
Low (<6.5%)	$131	$371	$598	$502	$729
Medium					
Light option	160	742	1196	902	1356
Heavy option	160	1484	2393	1644	2553
High (>12%)					
Light option	1080	1484	2393	2564	3473
Heavy option	1080	2968	4785	4048	5865

Exhibit 6.3 extends these estimates over the first year of a ramp enforcement program. The annual cost of this program in the Los Angeles areas would be $172,205 under a strategy of overtime enforcement and $252,577 if new officers are hired. The CHP Area bearing the heaviest enforcement requirement is Central Los Angeles, which will require an estimated 1,728 person hours of special enforcement. Because the officers can cover only four hours per day, number of hours is roughly the equivalent of two additional officers. The special enforcement requirements of the first year of the enforcement program would parallel those occuring during the last year of the current study. Whereas enforcement on any single ramp will be lighter during the proposed program (occuring semi-annually rather than quarterly) more ramps will receive the attentions of special enforcement officers. As noted, the

Exhibit 6.3

FIRST YEAR COST OF RAMP ENFORCEMENT PROGRAM BY CHP AREA

Area	No. of Ramps	Estimated Violation Categories			Personnel Needs (hours)		Estimated Cost	
		High	Medium	Low	Routine	Special	Overtime Option	New Personnel
SOUTHERN DIVISION								
Glendale	8	0	0	8	47	128	$ 4,019	$ 5,835
Santa Fe Springs	25	1	8	16	200	736	21,538	31,982
Central L.A.	25	13	9	3	710	1,728	55,941	80,461
West L.A.	15	3	6	6	223	672	20,568	30,103
South L.A.	22	4	14	4	317	1,120	33,058	48,951
East L.A.	15	1	9	5	142	608	17,273	25,901
West Valley	16	2	8	6	189	672	19,808	29,344
Division Total	126	24	54	48	1,828	5,664	$172,205	$252,577
BORDER DIVISION								
Westminster	23	5	10	8	360	1,088	$ 33,277	$ 48,715
Santa Ana	13	5	6	2	296	800	25,168	36,520
San Diego	6	0	0	6	35	96	3,008	4,371
El Cajon	4	0	0	4	24	64	2,021	2,929
Division Total	46	10	16	20	715	2,048	$ 63,474	$ 92,535
GOLDEN GATE DIVISION								
San Jose	2	0	1	1	13	64	$ 1,775	$ 2,683
STATE TOTAL	174	34	71	69	2,556	7,776	$237,454	$347,795
OVERALL AVERAGE (per ramp)					15	45	$ 1,365	$ 1,999

cost of enforcement during succeeding years can be expected to drop as special enforcement lowers violation rates on previously unenforced ramps.

6.1.3 Costs and Benefits of Enforcement

There are at least two ways of determining whether the cost of enforcing ramp bypass lanes is balanced by the benefits received from that enforcement activity. One may take a narrow view of the cash flows involved and ask whether the fines received from cited violators cover the cost of officer time and court procedures. Alternatively, one may take a broader view and ask whether the investment of officer time is commensurate with the improvements in freeway flow and reduced accidents that can be expected to accompany reductions in the violation rate. This subsection addresses both of these questions.

Net Cash Flow. HOV enforcement need not result in a net drain on public finances. Each time a fine is assessed from a cited violator, the dollar amount of the fine is allocated to the treasury of the city or county where the offense occurred. Although the revenue is not returned to the enforcement agency, it is relevant to ask from a societal standpoint whether the dollars expended by that agency are matched or exceeded by the dollars paid to local jurisdictions by cited violators.

Exhibit 6.4 tabulates the daily revenues accruing to the local jurisdiction from the assignment of a single officer to ramp enforcement duty in each CHP area included in the study. In computing net citation revenues, a court cost of $8.00 per citation has been assumed for processing.[3] In most areas, the cost of enforcing ramps with medium and high violation rates is amply covered by the net revenues accruing to the local jurisdictions even if the full cost of a newly hired officer is ascribed to the four-hour enforcement period. This is not generally true for low violation ramps. In areas with high bail schedules (Glendale and South Los Angeles), the fines collected easily exceed the cost of enforcement and processing even on low violation ramps. This is not the case in the Santa Fe Springs Area and the jurisdictions covered by the CHP's Border Division. In San Diego, the bail schedule for the 21655.5 occupancy violation is so low ($13.50 per violation) that it does not begin to reflect the cost of enforcement. Outside of the Border Division, however, HOV ramp enforcement can be said to be "profitable" in the sense that each citation brings considerably more

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[3] This represents the average court costs for all types of citations, as tabulated by the CHP's Long Range Planning Section (Telephone conversations with John Keller).

Exhibit 6.4

NET CASH FLOW ANALYSIS OF THE COSTS AND RETURNS OF RAMP METER BYPASS LANE ENFORCEMENT

	Average Citation Revenue			Daily Citations per Officer Assigned					
				High Violation Ramps		Medium Violation Ramps		Low Violation Ramps	
CHP AREA	Revenue/ Citation	Processing Cost	Net Income	Citations/ Officer	Net Revenue	Citations/ Officer	Net Revenue	Citations/ Officer	Net Revenue
West L.A.	$39.00	$8.00	$31.00	16.7	$517	10.2	$316		
Central L.A.	24.50	8.00	16.50	17.0	281	18.2	300		
Westminster	25.00	8.00	17.00	5.9	100*	6.6	112*	4.5	$ 77*
Santa Fe Springs	40.38	8.00	32.38	5.4	175	4.4	143	3.0	98*
Glendale	37.30	8.00	29.30			6.4	188	6.6	192
South L.A.	35.50	8.00	27.50			8.7	239	9.1	251
West Valley	37.75	8.00	29.75			7.4	219		
Santa Ana	25.00	8.00	17.00			5.3	90*		
San Diego	13.50	8.00	5.50					6.8	37*
El Cajon	13.50	8.00	5.50					2.4	13*
San Jose	26.50	8.00	34.50			4.8	166		
Average	$28.90	$8.00	$20.90	11.3	$268	8.0	$197	5.4	$111

Officer Cost per Four-Hour Special Enforcement Assignments

$150 if newly hired for special enforcement
$ 93 if senior officer overtime

*Indicates a net revenue lower than the cost of enforcement money into the treasury of the local jurisdiction than it costs different agencies to issue and process.

Overview of Freeway Benefits. Since occupancy violations on ramp meter bypass lanes threaten the integrity of the ramp metering system, a broader view of the costs and benefits of ramp enforcement must encompass the improvements in freeway performance resulting from ramp metering. These benefits manifest themselves in two important measures of effectiveness: reduced trip times and reduced accident rates. Ramp metering also affects fuel consumption and air quality, but these impacts are at least an order of magnitude lower than the impacts on travel time and safety (see Reference 7).

Empirical evidence of reduced travel times may be found in a CALTRANS study of "The Effects of Ramp Metering on City Streets." (Reference 12) This study summarizes the results of eleven ramp metering projects in Los Angeles, reporting a net reduction of 3,920 vehicle hours per day over all of the projects. Assuming 1.3 passengers per vehicle, this amounts to 5,096 passenger hours per day. This total is composed of relatively small (under 5 minutes per day) savings for a large number of travelers. The "Manual on User Benefit Analysis of Highway and Bus-Transit Improvements" (Reference 1) suggests that time savings of this magnitude for work trips be valued at 6.4% of the average hourly family income, or roughly $0.80 per hour in 1981 dollars. By following this guidance and allocating the dollar value of benefits among the 111 ramps in the 11 projects sampled by CALTRANS, a net benfit of $9,255 per ramp per year can be attributed to improved freeway flow.

Ramp metering also has a measurable impact on freeway accident rates. As discussed in Section 4.2.1 (see Exhibit 4.3), accident rates on twenty-two metered freeway segments covering 146.7 miles dropped from 1.15 accidents/MVM to 1.03 accidents/MVM following the introduction of ramp metering. This drop represents an average savings of 64.6 accidents per year. These accidents predominantly involve property damage ony (see Section 4.2.1). Using CALTRANS report on "1980 Accident Data on California State Highways" (Reference 11) to estimate accident costs, the mixture of:

.1% Fatal accidents @ $120,000 per accident;
26.3% Injury accidents @ $5,400 per accident; and
73.6% Property damage accidents @ $1,700 per accident

gives a cost per accident of $2,790 on urban freeways. Applying this cost to the 64.6 accidents per year saved on the sample freeways and allocating the savings among the 221 ramps involved gives an annual savings of $815.00 per ramp attributable to accident reduction on the freeway.

The estimate of time savings and accident reductions cited above are based on empirical measurements made on freeway segments containing metered ramps with and without carpool bypass lanes. It is difficult to assess the relative contribution of the bypass lanes alone to these savings.[4] Most of the bypass lanes in the Los Angeles and San Diego areas were installed prior to the start of this study, and a detailed analysis of their individual impacts on carpooling and freeway performance was beyond the scope of this investigation. In interpreting the empirical benefits of ramp control, however, it is important to recognize that these benefits reflect the combined results of both ramp metering and priority entry.

Although it is difficult to assess the individual contribution of carpool bypass lanes to increased carpooling and improved freeway performance, one aspect of the benefits provided by priority entry lends itself to separate quantification. By providing priority entry to high occupancy vehicles, ramp bypass lanes reduce the total number of person-hours consumed waiting at meters on the ramps themselves. If it is assumed that the total number of vehicle hours of delay remains constant when a bypass lane is installed (that is, that single occupant vehicles are made to wait proportionately longer to keep the ramp entry rate constant), then the savings in passenger hours can be calculated from a knowledge of the average ramp delay. For the sample of ramps with bypass lanes considered in this study, the average ramp delay was 10.8 vehicle hours. The benefit in confining this delay to single occupant vehicles, while providing free entry to carpools, amounts to a savings of 3.56 passenger hours per ramp per day, or an estimated $717 per year.

Overview of Ramp Metering Costs. CALTRANS currently estimates[5] the cost of installing a traffic-responsive ramp meter to be $27,000 per ramp (1981 dollars). If a carpool bypass lane is provided as well, an additional $4,000 is required, bringing the total installation cost to $31,000. Operating costs total $1,500 per year, while maintenance costs average $3,000 per ramp per year. The cost of electrical power consumes an additional $235 per ramp per year. (Reference 28) In addition, when a bypass lane is installed along with a ramp meter, ramp accidents can be expected to increase by .159 accidents per ramp per year (see Section 4.2.2). At the established rate of $3,028 per accident, that increase ammounts to an additional cost of $481 per year. A comparison of these operating costs with the average benefits allocated to an individual ramp provides some insight into the price one might be willing to pay to

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[4] It is particularly difficult to assess the impact of carpool bypass lanes on the formation of new carpools. A CALTRANS study of twenty-three of the earliest bypasses installed suggests that the bypasses themselves were responsible for a 20% increase in carpooling. (Reference 14) Observations on the twelve new bypass lanes installed on LA405 in the course of this study, however (see Section 2.1.3), showed no significant increases in carpooling after one year of bypass lane operation. This general trend is not surprising, since the earliest bypass lanes installed were carefully chosen for their carpool-generating potential. (Reference 16)

[5] Information supplied by Gary Bork in an internal CALTRANS memorandum on October 1, 1981.

enforce bypass restrictions. The display below summarizes the average benefits and costs associated with an individual metered ramp and bypass lane.

AVERAGE BENEFITS AND COSTS OF METERED RAMP/BYPASS LANE COMBINATION

INITIAL INVESTMENT
$27,000 (ramp meter)
4,000 (bypass lane)

Total Investment:
$31,000

ANNUAL COSTS	AVERAGE ANNUAL BENEFITS
$1,500 (operations)	$9,255 (improved freeway travel time)
3,000 (maintenance)	815 (reduced freeway accidents)
235 (power)	717 (priority entry time savings)
481 (increased ramp accidents)	$1,577n (energy and vehicle cost savings from increased carpools)
x (enforcement)	
Total Annual Costs:	Total Annual Benefits:
$ 5216 + x	$10787 + 1577n (where n=number of new carpools formed)

As explained earlier, it is difficult to estimate with confidence the number of carpools formed as a result of a single ramp meter bypass lane. The formation of a relatively small number of new carpools from the ranks of single-passenger autos can have a significant impact on the average benefits in the above equation. If the annual savings associated with each newly formed carpool are $1,577,[6] the average annual benefits resulting from different levels of carpool formation are listed below:

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[6] This number represents an estimate of the operating cost-savings realized when the autos previously used by carpoolers are freed from the daily commute journey. Commuter Computer in Los Angeles has estimated that a total of 4164 vehicle miles are saved annually by each new carpooler. (Reference 29). The average number of occupants in carpools using the study ramps is currently 2.36, giving an annual savings of 9827 vehicle miles per carpool. At 16.05 cents per mile, the average cost of operating a passenger car on a freeway (including an allowance for gasoline, oil, tires, maintenance and the mileage-related costs of depreciation and accidents), as reported in Reference 1 (updated to reflect cost increases since the 1975 base year), each new carpool saves its occupants $1,577 per year.

Number of new carpools formed from ranks of single passenger autos	Estimated Carpool Savings ($/year)	Average Annual Benefits Metered Ramp/Bypass Lane Combination ($/year)
0	0	$10,787
1	$1,577	12,364
2	$3,154	13,941
5	$7,885	18,672
10	$15,770	26,557
20	$31,540	42,327

Even without knowing the exact number of carpools formed as a result of a new ramp meter bypass lane, or the precise amount of vehicle travel time saved as a result of these carpools, several observations can be made regarding the relative benefits and costs of ramp meter bypass lanes:

1. A ramp bypass lane does not have to generate many new carpools before the annual benefits of the metered ramp/bypass lane combination overwhelm the annual costs. This observation holds even if the highest level of proposed enforcement costs is incurred.

2. Even if a bypass lane generates no additional carpools, the average annual benefits from installing a ramp meter and bypass lane exceed the annual costs of ramp operations, maintenance, and increased ramp accidents.

3. If it is assumed that different levels of enforcement will have no influence on the number of carpools generated by a bypass lane,[7] it is possible to use the above benefit cost relationship to compute the maximum amount one should be willing to pay for enforcements on ramps with meters and bypass lanes. By setting $n = 0$ in the above equation (i.e., assuming no additional carpools are formed, and ignoring enforcement, the difference between annual benefits and costs is $5,571 per ramp. In the case of those ramps on which meters and bypass lanes have already been installed (i.e., those ramps on which the initial investment is an irretrievably sunk cost), it can be argued that $5,571 represents a crude upper bound on the <u>average</u> cost one should be willing to pay for enforcement at a single ramp per year.

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[7] If violation rates were to approach 100% in the absence of enforcement, this assumption would clearly be untenable, since there would be no queue at the meter and no advantage for carpoolers. As a practical matter, however, enforcement is not likely to affect carpool formation measurably on ramps operating at more realistic violation levels. While enforcement will cause the queue lengths to increase somewhat (see Section 2.1.7), the resultant increases in meter delay are likely to be insignificant when measured against the larger perceived delays resulting from drivers' tendencies to overestimate any delay.

Enforcement Benefits. The above comparison provides some insights into the rough order of magnitude of allowable ramp enforcement costs. However, this static comparison ignores many of the dynamic impacts of enforcement. It is possible that an investment in special enforcement might pay for itself by further improving freeway flow and reducing accident rates below the empirical levels measured under conditions of routine enforcement. Alternatively, driver distraction accompanying roadside enforcement might so disrupt freeway flow that total benefits will be reduced. Additional analysis is necessary if the full impact of enforcement on freeway performance is to be better understood. One mechanism for this analysis is the FREQ6PE modeling package used in Chapter 3 to investigate the impacts of different violation rates on freeway flow.

Exhibit 6.5 replots the results of the FREQ6PE analysis (see Section 3.1.2) to emphasize the impact of different violation rates on freeway travel time and total passenger travel time (including the effect of ramp delays). Three different assumptions are made regarding the use of bypasses on metered ramps:

1. All metered ramps have bypasses;

2. Half the metered ramps have bypasses;

3. No ramps have bypasses.

Under the assumption that all metered ramps have carpool bypasses, the effect of violations on travel time is much sharper than under the assumption that only half the ramps have bypasses. With no bypasses, violations can have no impact on travel time. With no bypasses, however, passenger travel time will be higher than in a system with bypasses and low violation rates, because carpools carrying two or more passengers will have to wait at meters along with single-occupancy vehicles. Naturally, enforcement costs will be proportional to the number of bypass lanes.

The relative value of using enforcement to reduce ramp violation rates from 20% to 10% on the modeled freeway is sketched on the curves of Exhibit 6.5. In terms of passenger time, a reduction from 20% to 10% on a freeway with all of its ramp meters bypassed is depicted as delta A on Exhibit 6.5. The equivalent value for a system with 50% of all ramps metered appears as delta A'. The lower chart traces the impacts of violations on vehicle travel time on the freeway itself. Since this measure reflects freeway congestion, it has been used as a surrogate for the freeway accident rate. The scale at the right hand side of the lower chart identifes those two points for which accident data can be inferred. With no ramp metering (i.e., 100% violations with all meters bypassed), accident rates of 1.15 accidents/MVM were recorded on a sampling of Los Angeles freeways (see Section 4.2.1). With roughly 50% of all ramps on the sample segments bypassed, and ramp violation rates of 12.7%, accident rates of 1.03 accidents/MVM were recorded.

Exhibit 6.5

PASSENGER AND FREEWAY TRAVEL TIME AS A FUNCTION OF RAMP VIOLATION RATES FOR THREE LEVELS OF BYPASS LANE INSTALLATION

(Showing the Impacts of Reducing Ramp Violation Rates from 20% to 10% and from 10% to 6%)

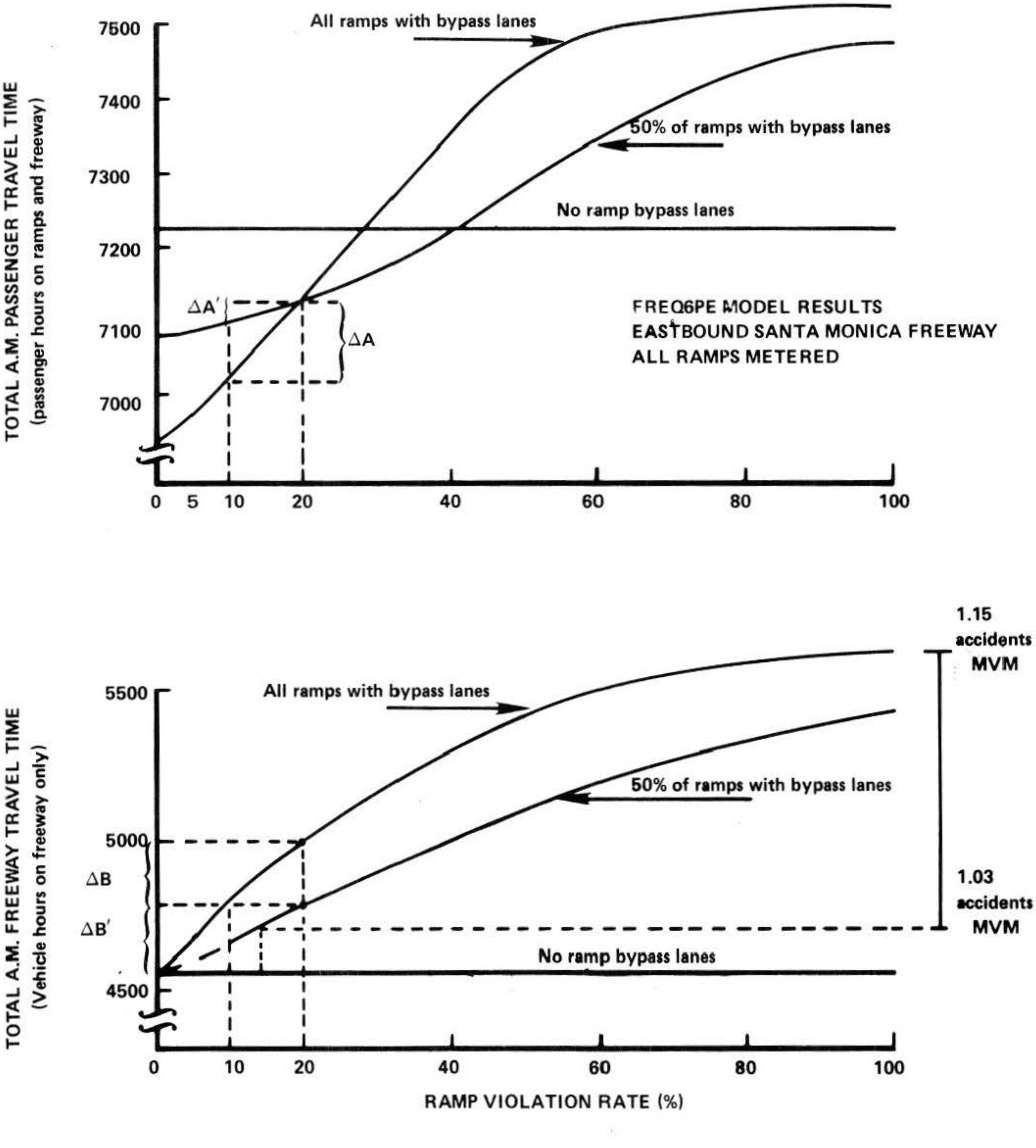


Exhibit 6.6 translates the travel time and accident reductions from the graph in Exhibit 6.5 into dollar values using the factors developed earlier in this section. Considering both time savings and accident reductions, the freeway model predicts the following annual savings for the two situations tested.

SAVINGS PER RAMP PER YEAR
ACCOMPANYING VIOLATION REDUCTIONS
from 20% to 10%

ALL RAMPS BYPASSED:	$2,506
50% OF RAMPS BYPASSED:	$2,134

By making a number of comparisons similar to those calculated above, it is possible to plot the cost of violations as a function of ramp violation rates on the model freeway. Exhibit 6.7 contains such a plot for two different ramp metering strategies (meters set to accommodate 0% or 5% violation rates) and two different levels of bypass lane implementation (bypasses on 50% or 100% of the metered ramps). A consideration of the special enforcement levels called for in the proposed enforcement program suggests that the out-of-pocket enforcement costs are roughly commensurate with their likely impact on violation costs. In the case of the example worked out earlier in Exhibit 6.6, a 20% violation rate on a ramp would elicit special enforcement efforts ranging from $1,500 to $4,800 per year (averaging $2,900) with routine enforcement costing an additional $1,080. Based on the experience gained in the current study (and summarized in the matrices of Exhibit 6.1), the likely result of a year of special enforcement effort would be a reduction to a 10% violation rate. Depending on the relative number of bypass lanes in the system, this reduction represents an annual savings of $2,100 to $2,500 per ramp. With violation rates at 10% at the start of the second year, the program calls for special enforcement levels costing from $750 to $2,400 per ramp per year with routine enforcement amounting to an additional $160. These enforcement costs may be viewed either as an investment to reduce violation rates further (in which case the cost of enforcement is likely to exceed the measured results) or as a necessary expense to keep violation rates from returning to 20%. (In which case the cost of enforcement can be viewed as a bargain, since the penalty for returning to the previous level will range from $2,100 to $2,500.) Since violation levels have traditionally risen in the absence of special enforcement, it is reasonable to expend a certain amount of effort to maintain the lower violation levels resulting from increased enforcement. Viewed in this light, the out-of-pocket costs of the proposed enforcement program can be seen to be roughly commensurate with the costs incurred if violations are allowed to increase along the curves of Exhibit 6.7.

Additional Enforcement Costs. The out-of-pocket enforcement costs borne by the enforcing agency are not the only costs incurred in undertaking special ramp enforcement duties. As indicated in Section 2.1.7, when citations are issued within the view of drivers on the mainline freeway, driver distraction can cause additional congestion.

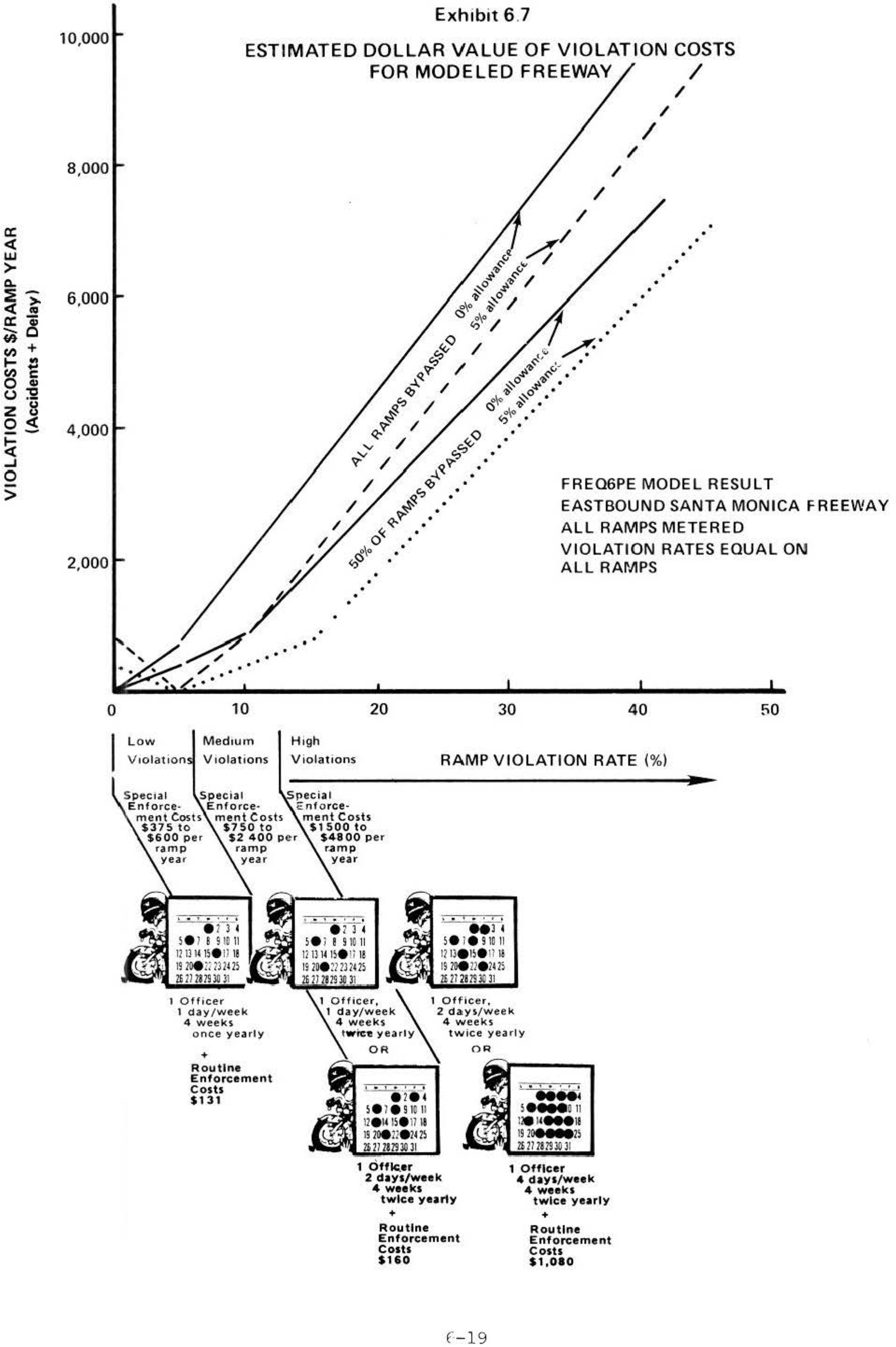
Exhibit 6.6

ESTIMATED DOLLAR VALUE OF VIOLATION REDUCTIONS FROM 20% TO 10% FOR MODELED FREEWAY

Violation Reduction from 20% to 10%	Change In		Annual Savings (total $)	Savings per Ramp ($/year)
	Passenger or Vehicle Hours per Day	Accidents/Year		
All Ramps with Bypasses				
Change in Passenger Time ΔA	−109		$21,974	$1,997
Change in Vehicle Time ΔB	−212	−2.01	5,608	509
Total Savings			$27,582	$2,506
50% of Ramps with Bypasses				
Change in Passenger Time ΔA′	−44		$ 8,870	$1,612
Change in Vehicle Time ΔB′	−108	−1.03	2,873	522
Total Savings			$11,743	$2,134

Exhibit 6.7

ESTIMATED DOLLAR VALUE OF VIOLATION COSTS FOR MODELED FREEWAY



The effects of this added congestion are not inconsequential when measured against the costs of enforcement and the benefits of the ramp metering program. Section 2.1.7 cites the case of three Los Angeles ramps in which mainline speeds upstream from the ramps dropped significantly on days when special ramp enforcement was carried out in full view of mainline commuter traffic. Although speeds increased slightly downstream from the ramps, the net effect was a reduction in the freeway flow rate. By averaging speed observations over a 2-1/2 hour period, the magnitude of this reduction can be estimated.

Exhibit 6.8 summarizes the estimated impacts of in-view ramp enforcement on mainline flow for the three Los Angeles ramps. On the average, freeway performance declined by 80.7 vehicle hours during the peak commuting period on each day of special enforcement. Since the average improvement in freeway flow resulting from eleven metering projects encompassing 111 metered ramps was 356 vehicle hours per day (Reference 12), it is clear that hefty enforcement requirements can make significant inroads into the benefits of ramp metering. If only one ramp per day on a metered section of roadway were to require special enforcement, and if enforcement were carried out in full view of mainline flow, the assembled evidence suggests that this enforcement activity would reduce the benefits of an average metering program by roughly 23%.

Another way of viewing the deleterious effect of special enforcement on mainline flow is to include this effect in the perceived cost of enforcement. By applying the same cost structure ($.80 per passenger hour) used in estimating metering benefits, the following annual costs could be attributed to the different levels of the proposed enforcement program to reflect the disruptive impact of special enforcement on mainline traffic.

ENFORCEMENT COSTS
INCLUDING DISRUPTIVE EFFECTS OF IN-VIEW ENFORCEMENT

RAMP VIOLATION RATE	ENFORCEMENT FREQUENCY (DAYS/YEAR)	ESTIMATED FLOW DISRUPTION ($/YEAR)	AGENCY ENFORCEMENT COSTS ($/YEAR)		TOTAL ENFORCEMENT COSTS ($/YEAR)	
			Overtime	New Officers	Overtime	New Officers
Low	4	$336	$502	$729	$838	$1065
Medium	8	$671	$902	$1356	$1573	$2027
	16	$1342	$1644	$2553	$2986	$3895
High	16	$1342	$2564	$3473	$3906	$4815
	32	$2684	$4048	$5865	$6732	$8549

Thus, when ramp enforcement is conducted in full view of mainline traffic, the added congestion significantly increases the cost of enforcement. This increase provides a strong argument for providing refuge areas out of the view of mainline flow wherever possible, and selecting less intensive enforcement levels when enforcement must be conducted on the mainline shoulder.

Exhibit 6.8

IMPACT OF SPECIAL RAMP ENFORCEMENT ON MAINLINE FLOW RATES*

Ramp	**Freeway**	**Upstream Flow Change (vehicle hr/peak period)**	**Downstream Flow Change (vehicle hr/peak period)**	**Net Flow Change (vehicle hr/peak period)**
Manning	LA 10	−59	+1.55	−57.5
Florence	LA 11	−117	+43.9	−73.1
Inglewood	LA 405	−143.7	+32.3	−111.4
Average		−106.6	+25.9	−80.7

*Assumes speed observations extend 1/2 mile upstream and downstream from ramp over a 2.5 hour peak period.

Additional Perspective. Much of the above analysis relies on average values of benefits and costs, some of which have been generated under the unrealistic assumption that all ramps are created equal. As noted in the design section (Section 3.1.2) however, all ramps are not equal, and it is possible that a low level of violations on a few critically positioned ramps can negate most of the positive impacts of ramp metering. Such ramps can often be identified in the early stages of design, so that the threat can be countered through restrictive metering or the elimination of a bypass lane.

Reliance on average values can also hide the fact that bypasses on some lightly travelled ramps offer little time savings to carpoolers and may not be able to generate benefits proportional to their cost of enforcement. Of thirty-four Los Angeles bypass lanes studied closely in this analysis, fourteen (41%) saved carpoolers less than 2.0 passenger hours per day per ramp. This savings is not sufficient to justify the annual cost of $502 required for the lowest level of enforcement identified in the proposed program, even without considering the likelihood that enforcement on these ramps will affect mainline flow adversely, or the certainty that the time saved by carpoolers will be partially offset by additional delays for single occupant vehicles. All of these costs would easily be offset if the bypass lanes influenced the formation of new carpools. Since carpoolers on the fourteen ramps save an average of only eleven seconds daily, however, whatever carpooling incentives the bypass lanes offer must rely heavily on the power of suggestion.

The effectiveness of ramp bypass lanes in encouraging the formation of new carpools is not well understood. However, even a modest degree of success in this area will generate enough benefits to offset both the cost of enforcement and the average initial investment required to install the bypass lane itself. The savings from two new carpools operating 2.25 years (the average life of a carpool in Los Angeles -- see Reference 29) would easily justify the $4,000 incremental investment needed to install the bypass lane initially, even at today's high rates of interest. If a lane is responsible for generating four new carpools, moreover, the savings in operating costs will counterbalance not only the average initial investment, but also the cost of the highest level of enforcement contemplated in the proposed program and the adverse impacts of that enforcement on mainline freeway flow.[8] While bypass lanes should not be installed where violations are likely to have a disproportionate impact on freeway performance, where design problems exist, or on some lightly travelled ramps, the benefits from even the most modest success in generating new carpools serve as a compelling argument for bypass lane installation.

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[8] If the initial installation cost significantly exceeds the $4,000 average value, as may be the case if new construction is required in installing the bypass lane, the ability of benefits to exceed costs is not so obvious. Each case will need to be considered individually, but lightly traveled ramps are not likely to generate enough new carpools to offset major construction investments.

6.2 MAINLINE HOV LANES AND THE SAN FRANCISCO/OAKLAND BAY BRIDGE

The benefit/cost analysis of mainline HOV lanes follows the same procedure outlined in the previous section. However, it is important to keep these important different characteristics of the mainline HOV lanes and the San Francisco/Oakland Bay Bridge in mind:

- Routine enforcement on the mainline projects is much higher than for the ramps. The small number of mainline HOV lane projects and their dispersion throughout the state reduces the burden of enforcement for any one CHP area to manageable levels.

- The current study found that violation rates did decline after special enforcement but that these effects were short-term, fading within a few months.

- Violation rates are currently considered to be at a manageable level on the facilities. Although lane violation rates of above 20% occur, the number of violators when compared to the total facility use is very small, less than 2% of the total freeway for each of the projects.

6.2.1 Proposed Program

The proposed program is aimed at maintaining the violations at the present level or lower. the San Bernardino Busway and the San Francisco/Oakland Bay Bridge should be enforced at present levels. Alameda 580 should be enforced slightly more while Marin 101 could possibly be enforced less. The suggested program is as follows:

1. Monitoring. CALTRANS (District 07) shall monitor violation rates on Marin 101, Alameda 580, and the San Francisco/Oakland Bay Bridge at least once annually. CALTRANS (District 04) shall monitor violation rates on the San Bernardino Busway quarterly. Lane violation rates will be calculated and supplied directly to the Captain of the local CHP Area responsible for enforcement. In addition, the lanes should be observed if complaints about violators rise markedly at any time or if new enforcement policies are adopted by the CHP. In particular, Marin 101 should be monitored at least four times within the next year to see if the increased levels of enforcement are reducing violation rates.

2. Special Enforcement. The recommended special enforcement program is outlined in Exhibit 6.9. The program and rationale are described below for each of the HOV lane projects.

   - Marin 101. The current level of four (sometimes five) motorcycle officers a day for each weekday should remain the same pending results from future CALTRANS violation counts. If the violation rate drops to a lower level (20% or less) then

Exhibit 6.9

ENFORCEMENT PROGRAM FOR MAINLINE HOV LANES AND THE SF/OAKLAND BAY BRIDGE

Route	CHP Area	Recommended Special Program				Existing Routine Program				Total Cost	Comments
		Officers Assigned Specifically to HOV Lane Enforcement		Duration	Estimated Cost/Year (Rate Level)	Officers on Normal Beat (Daily)		Total Monthly Hours Enforcing HOV Lanes*	Estimated Cost/Year (Rate Level)		
		AM	PM			AM	PM				
Marin 101	Marin	1	4	Daily (20 days/ month)	$111,600 (Overtime) $180,000 (New hire)	4	4	Negligible	Negligible	$111,600 (Overtime) $180,000 (New hire)	Enforcement levels are probably high. As long as next CALTRANS count does not indicate an increase in violations, the PM officers should be reduced from four to two.
Alameda 580	Hayward	2	2	2 days/week 2 weeks Twice annually	$1,488 (Overtime)	1	1	32	$8,582 (Senior Officer)	$10,070	Only one peak period need be enforced each wave. Alternate so that each peak period is enforced at least once a year.
San Bernardino Busway	East L.A.	4	1	2 days/week 4 weeks Twice annually	$7,440 (Overtime)	3	4	120	$32,184 (Senior Officer)	$39,624	Special Enforcement Units should focus on morning peak period and especially between 7:00 and 8:00 AM. Violations at this time can disrupt busway flow. Baldwin Park need not be enforced in PM by Special Enforcement Units.
	Baldwin Park	2	0		$2,976 (Overtime)	2	2	40	$10,728 (Senior Officer)	$13,704	
San Francisco/ Oakland Bay Bridge	San Francisco	4	0	4 days/week 1 week Four times annually	$5,952 (Overtime)	6	6	10	$2,676 (Senior Officer)	$8,628	Short bursts of intense enforcement seem to work best on the Bay Bridge.

Officer Rates:

- Senior Officer – $22.35/hour
- Senior Officer on overtime – $93.00 per four-hour period
- Newly hired officer – $150.00 per enforcement period (8 hours assigned to each enforcement period)

*Estimated from number of tickets written monthly the special enforcement unit should be reduced from four officers to two officers. Despite heavy enforcement during the study the violation rate has not dropped appreciably but may do so in the future if the present pool of violators "dries up." Even if the violation rate does not drop, it is recommended that two officers be removed as an "experiment" to see whether violations on Marin 101 are essentially insensitive to the enforcement level.

- Alameda 580. Prior to this study, the Hayward CHP Area had rarely assigned officers to special enforcement duties on Alameda 580, primarily because of personnel shortages and the need to focus enforcement efforts on the highly congested portions of Route 17 within the Area's jurisdiction. The two waves of special enforcement undertaken during this study appear to have arrested the long-term increase in violation rates that had been observed over several years. Based on this experience, it is recommended that two weeks of special enforcement be scheduled approximately twice a year with two officers during the PM or two officers during the AM peak period. Enforcement during one peak period has been found to reduce violations during the other peak period. The peak period enforced should alternate so that each peak is enforced at least once a year. If the violation rate rises in the next CALTRANS count (above 35% during the PM peak period), the duration of special enforcement can be increased to four weeks.

- San Bernardino Busway. Special Enforcement Units (S.E.U.s) should be specifically assigned twice yearly to busway enforcement. For four weeks, two days each week, a total of six officers in the AM and one in the PM should cover the partially separated section of the busway. Violations in the separated section are negligible and can be enforced by having one of the east Los Angeles officers drive through the busway once in the morning. Enforcement in the morning is more crucial since peak congestion hours occur between 7:00 and 8:00 AM. During these times, violators can cause slow downs in the carpool lane. If the next CALTRANS violation count is above 10% for either of the peak periods, the number of special enforcement days per week can be increased to four.

- San Francisco/Oakland Bay Bridge. The CHP currently has a policy of assigning officers specifically to Bay Bridge HOV lane enforcement when they receive complaints or when the Bridge Manager informs them that violations are increasing. During the study, the most effective enforcement strategy seemed to be short intense bursts of highly visible enforcement. Thus, the proposed program recommends the use of four officers for four days for one week. During the study period, three waves of enforcement were tried. Although violation rates are presently at the 5 to 8% level, they rose at times to over 10% between waves, presumably because routine enforcement of the toll lane is minimal. For this reason, the toll lanes should be enforced slightly more frequently, approximately four times a year. The duration of special enforcement can be increased from one to two weeks if violation rates rise above 10%.

3. Routine enforcement. Routine enforcement by officers on their normal beat is also documented in Exhibit 6.9. The present level of routine enforcement should be maintained on each of the projects. Enforcement by normal beat officers is sporadic on Marin 101 and on the San Francisco/Oakland Bay Bridge. On Marin 101, special enforcement is so high and enforcement of the lane by normal beat officers in patrol cars is so difficult that enforcement is left to the special patrol officers. On the San Francisco/Oakland Bay Bridge, the officers will pull over violators as they drive through the facility but will not normally station themselves at the bridge for long periods of time.

   Normal beat enforcement of the HOV lanes currently account for the vast majority of the tickets written on Alameda 580 and on the San Bernardino Busway. The HOV lane portion of Alameda 580 covers about half of the normal officer's beat. Since violations are quite frequent, nearly 60 tickets a month are normally written by the officer on duty. The San Bernardino Freeway officers spend most of their time patrolling in the general traffic lanes. During the two to three hours of peak congestion, however, most of the officers tend to position themselves on the buffer shoulder where they can observe both the mainline lanes and the busway. As a result, the routine beat officers normally write between 200 and 300 HOV lane tickets in a month.

6.2.2 Program Cost

Estimates of program costs have been included in Exhibit 6.9. The range of costs shown for special enforcement of Marin 101 reflects two different costing assumptions. The lower value, $112,000 per year, reflects the cost of senior officers on overtime. The higher value, $180,000, uses the assumption that the officers assigned to special enforcement would not have been needed at all if there were no HOV lanes. This higher value therefore reflects the full 8-hour cost of assigning new officers to special enforcement. For the other locations, the special enforcement needs are small enough that they would not justify the hiring of new officers and the cost of a senior officer on overtime is used. An hourly rate for a senior officer is used for costing the officers on a normal beat.

The costs for enforcement of the HOV lane are quite high. Costs for enforcing Marin 101's HOV lane are easily over $112,000 a year and can range up to $180,000 depending on the assumptions used. The next most expensive project to enforce is the San Bernardino Busway, approximately $53,000 a year. The other projects cost considerably less: Alameda 580 costs about $10,000 a year; the San Francisco/Oakland Bay Bridge around $9,000. It should be noted, at least for <u>special</u> enforcement, that these costs are probably high because, unlike the ramps, officers enforcing the mainline lane are free to pursue other violators and their visibility has a chastening affect on other types of violations. In addition, special mainline enforcement officers are freer to respond to emergencies such as accidents.

6.2.3 Enforcement Costs vs. Citation Revenues

Exhibit 6.10 tabulates average revenues from special enforcement based on experience from the first wave of special enforcement on the HOV lanes. The number of tickets written by a special enforcement officer varied depending on the ease of enforcement. Officers on Alameda 580, where violators can be pulled over to the buffer or the dirt median, wrote the most tickets per hour. Officers on Marin 101, where violators had to be escorted across traffic to the shoulder area, wrote the lowest number of tickets per hour. In all cases the potential income from the citations more than covered the cost of a senior officer on overtime. In the case of Marin 101 the revenues did not cover the cost of a newly hired officer with a full workday charged solely to HOV lane enforcement. Marin 101 is also the one project where the cost of a new officer could apply because of the large personnel requirements of special enforcement. As will be seen, the monetary costs of violations on mainline HOV lanes are difficult to quantify.

6.2.4 The Costs of Mainline HOV Violations

As was seen in the previous section, the costs of enforcement are generally covered by the revenues brought in by citations. However, the primary aim of enforcement is not to increase cash flow but instead is to insure compliance with the law by discouraging violations. The broader "costs" of violations are covered in this subsection. As will be seen, the monetary cost of violations on mainline HOV lanes are difficult to quantify. The analyses <u>will</u> present general guidelines for determining a tolerable violation level on each of the projects.

An increase in the number of violators could result in two primary changes in freeway operations: (1) Accidents may rise as more violators make dangerous lane switches; (2) Mainline traffic flow improves at the expense of HOV lane traffic. A statistical connection between occupancy violations and accidents is tenuous given the rare nature of accidents and the complex factors that cause accidents. Some violations of the HOV lane are obviously dangerous. Any weaving into or out of the HOV lane, whether by violators or legitimate carpoolers, when there is a large speed differential between the reserved lane and mainline traffic raises the risk of an accident. This is already well recognized by the

Exhibit 6.10

NET CASH FLOW ANALYSIS OF THE COSTS AND RETURNS OF SPECIAL HOV LANE ENFORCEMENT

MAINLINE LANES AND TOLL PLAZA					
	Citation Revenue			Citations per Officer Assigned for Three-Hour Period	
Project	Revenue/ Citation	Processing Cost	Net Income	Citations/Officer	Net Revenue
Marin 101	21.00	8.00	13.00	8.9	\$116*
Alameda 580	26.50	8.00	18.50	16.7	\$309
San Bernardino Busway	28.50	8.00	20.50	10.0	\$205
SF/Oakland Bay Bridge	26.50	8.00	18.50	10.3	\$191

OFFICER COST PER THREE-HOUR ENFORCEMENT ASSIGNMENT

\$150 if newly hired for special enforcement (8 hours charged)
\$ 93 for senior officer overtime (four hours charged)

*Indicates a net revenue lower than the cost of enforcement and processing for newly hired officers

CHP and an officer's attention quite rightly focuses on such violations. Costs of this kind of violation cannot be given a monetary value since it is impossible to document the number of accidents attributed to illegal weaving maneuvers.

Occupancy violations which do not involve weaving need not increase accident levels, nor will violations on a mainline HOV lane necessarily increase trip times for other drivers, as they do on ramp bypass lanes. In order to understand the impact of mainline violations on traffic flow, it is necessary to explore the capacity of the HOV lane itself.

A simplistic scenario is that traffic flow on the mainline lane would actually improve as more violators switched over to the less-congested HOV lane. This would continue with little ill effects on carpool use until the HOV lane was as heavily used as the general lanes. Unfortunately, this simplistic scenario is unlikely for at least three reasons:

1. Any slight degradation of service for the HOV lane could result in a significant loss of carpools.

2. The "effective capacity" of an HOV lane is far less than the capacity of the general lanes.

3. Latent demand would quickly offset any mainline traffic-flow improvements gained by shifting some vehicles to the HOV lane.

These points are examined in more detail below, using data collected on the San Bernardino freeway and busway for purposes of illustration.

<u>What is the "Capacity" of an HOV Lane</u>? The Highway Capacity Manual states that uninterrupted-flow capacities for a multilane roadwayunder ideal conditions averages between 1,900 and 2,200 vehicles per lane per hour. Thus, it is not surprising that most highway engineers in California tend to associate the term "lane capacity" with a value of 2,000 vehicles per hour. But the San Bernardino Buswayis quite different from a multilane freeway. Its physical characteristics are akin to a long, two-way, one-lane roadway with no provisions for passing, no turnouts, and no ingress or egress. This is a roadway configuration that most highway engineers have not seen for decades, if at all. The closest current highway configuration to this would be a two-lane, two-way highway carrying heavy volumes in both directions. The Highway Capacity Manual states that, under such circumstances, "vehicular operation is sufficiently restricted to limit the flow in each direction to 1,000 passenger vehicles per hour." However, studies on the Busway have found peak flow rates (over 3 minute intervals) of 1,200 to 1,500 vehicles per hour with speeds of about 50 mph. How can these seemingly contradictory facts be reconciled?

The term "capacity," as it is commonly used by highway engineers, means "maximum possible capacity." This condition is generally achieved only with high-density traffic flow and speeds of about 35-40 mph.

Higher speeds can be sustained only when vehicular volumes are substantially below "capacity." On a typical California freeway, 55-mph speeds can be maintained only at volumes below 75% of capacity. Further limiting busway capacity, busway traffic includes a substantial percentage of buses (about 10%), a few of which are old and unable to consistently maintain 55-60 mph speeds.

Perceived vs. Actual Conditions. Motorists perceptions are a key ingredient in the capacity issue, because the busway's mode-shift attraction is heavily dependent upon its image as a high level-of-service facility. Previous busway studies found two key items regarding the perceived level of service on the busway (Reference 15):

1. The first finding was that motorists greatly overestimate delays, especially on the busway. As an extreme example, if a 60 mph vehicle gets queued behind a 50 mph vehicle at the very beginning of the busway, the trailing vehicle will be delayed by only 2.2 minutes over the entire 11 mile length of the busway. Most actual delays will be much less than 2.2 minutes. But many motorists estimated delays caused by slow-moving vehicles at 5 to 10 minutes. As busway volumes increase, the probability of thse "perceived major delays" grows quickly.

2. The second finding was that the freedom from delay-causing congestion or incidents produced a more predictable and reliable travel time. This permits many commuters, whose arrival at work must be punctual, to depart from home later than they would if their travel time was less certain. This yields a real time savings to many commuters. But as volumes approach capacity, the probability of busway congestion, such as might result from a minor incident on the shoulder, grows rapidly, and perceived reliability would drop correspondingly.

Thus, because HOV lane commuters tend to magnify actual delays, the assurance of reliable, free-flow conditions is essential if the HOV lanes are to encourage the formation of new carpools and give rise to additional bus ridership.

Capacity Defined. Since the busway must operate at or near the maximum legal speed if it is to maintain its important travel time advantage, all of the above considerations limit the maximum volumes that can be carried without experiencing an unacceptable degradation of operating speeds. For purposes of clarity, the term "maximum free-flow volume" will be used to distinguish this condition from "maximum possible capacity."

The maximum possible capacity of the busway lane is clearly much greater than the 1000 vehicles per hour that one might infer from the Highway Capacity Manual. Because drivers on the busway are virtually all regular commuters on the busway, they are well aware of the need to maintain speed. Indeed, slow-moving drivers are often rudely reminded of this need by a following vehicle. This minimizes the severe platooning that would otherwise occur, with a corresponding loss of capacity caused by large inter-platoon gaps.

This is not to imply that there is no platooning on the busway. Some platooning still does occur, as can be seen from a plot of 3-minute flow rates observed at a location near the midpoint of the busway (see Exhibit 6.11). The flow rates over 3-minute intervals show a variability of +/- 200 veh/hr when compared to the flow rates over the corresponding 15-minute intervals. Thus, there is some platooning (and associated loss of capacity) on the busway, but less than would be the case if most drivers were not regular customers.

Based upon the repeated observations of 1200 to 1500 vehicle per hour flow rates at speeds of 50 mph, it certainly appears that the busway lane is behaving more like a typical freeway lane than a one-lane roadway. These observations also show excellent agreement with the speed vs. volume curve for freeways, as appears in the Highway Capacity Manual (see Exhibit 6.12). Assuming that this speed vs. volume curve fits the San Bernardino Busway, speeds will begin to drop very quickly as volumes grow beyond the 1600 vehicle per hour rate; and, as observed above, at the 1600 veh/hr rate there will be substantial perceived delays. Even minor shoulder incidents such as accidents or enforcement activities are likely to induce breakdown conditions that will impair the reliability of busway travel time.

Thus, as a policy matter for purposes of determining enforcement requirements, it appears that the maximum free-flow volume of this and similar HOV lanes should be viewed as about 1400 vehicles per hour.

Violation Rates and Traffic Flow. Having estimated the maximum free-flow volume of an HOV lane, it is now possible to examine two important questions:

1. From the point of view of traffic flow on the HOV lane, is there an "acceptable" level of violations?

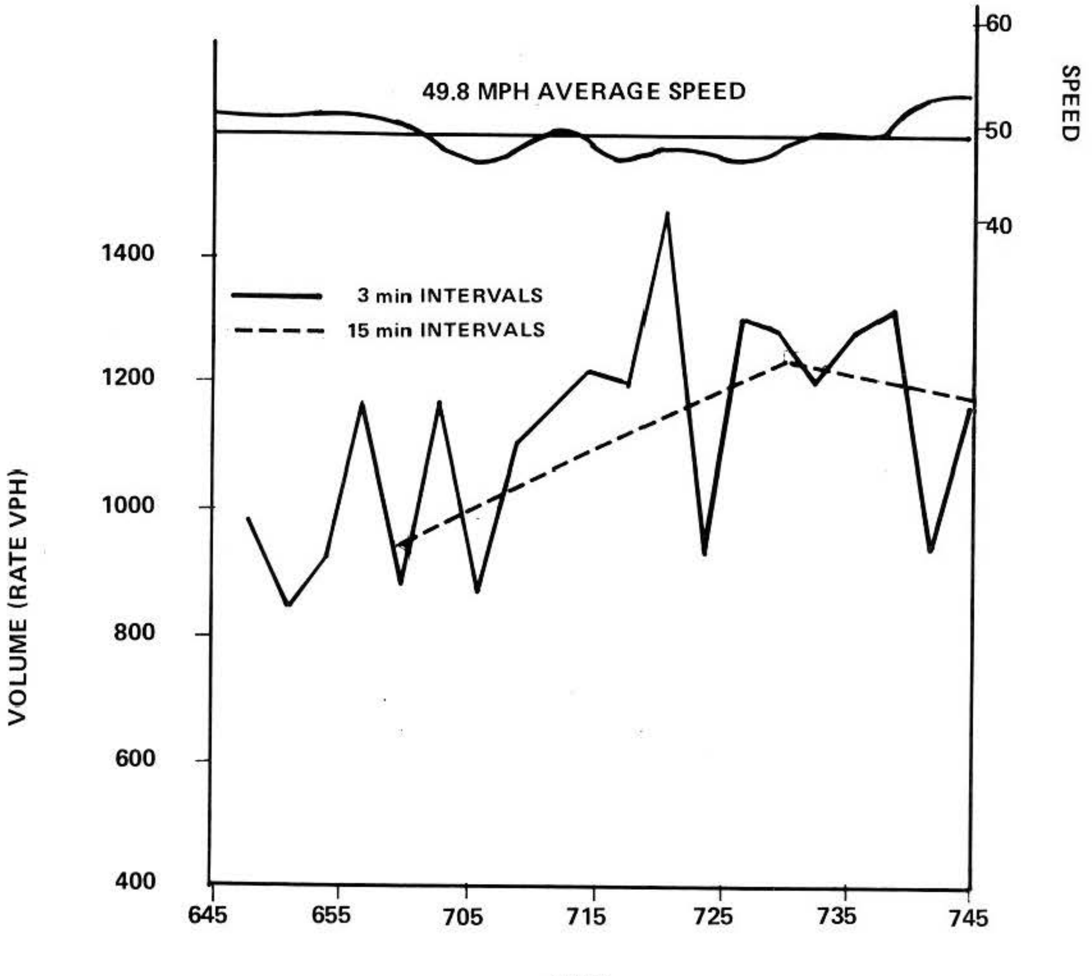
2. From the point of view of traffic flow on the entire freeway/busway facility, do violations actually improve traffic flow?

To answer these questions, it is necessary to first examine the current demand patterns for both the busway and the mainline freeway. Looking first at the freeway lanes, Exhibit 6.13 shows quite clearly that the mainline lanes are operating at maximum possible capacity for most of the AM 4-hour peak period.

The fact that the freeway is operating at capacity for three straight hours provides strong evidence that the demand greatly exceeds capacity for part of that 3-hour period. This is a common situation on many urban freeways -- the peak of the demand curve is "spread" into earlier and later times by the capacity limits of the roadway. This also implies that there is substantial "latent demand," with trips

Exhibit 6.11

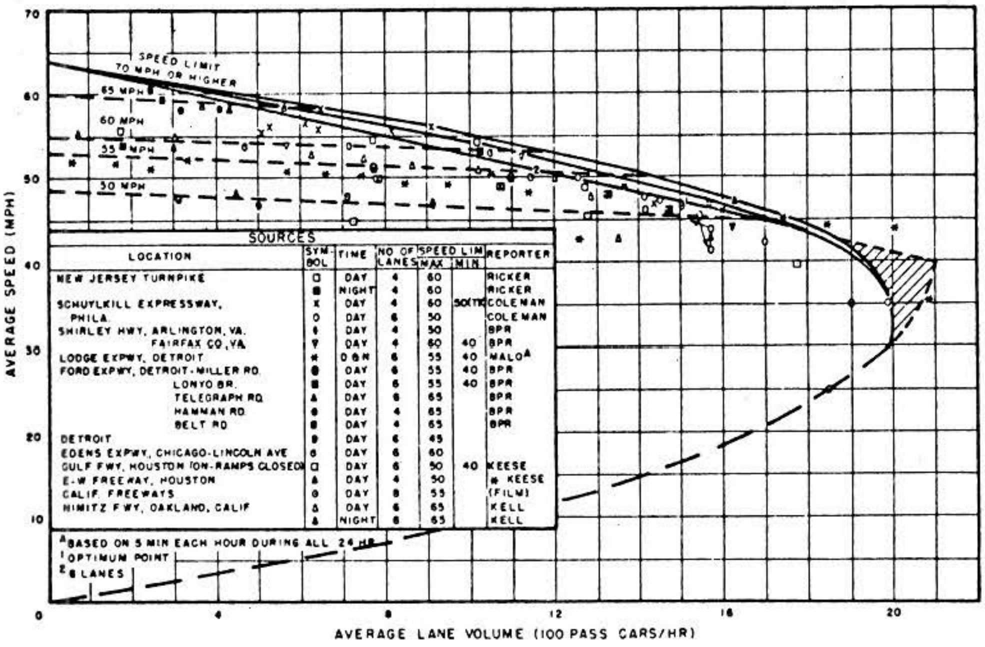
SPEEDS AND VOLUMES ON W/B SAN BERNARDINO BUSWAY



Observed at Marguerita Pedestrian Overcrossing
Grade ± 2%
Flow rates over 3 and 15 minute intervals

Exhibit 6.12

HIGHWAY CAPACITY



SOURCES

LOCATION	SYMBOL	TIME	NO OF LANES	SPEED LIM MAX	SPEED LIM MIN	REPORTER
NEW JERSEY TURNPIKE	□	DAY	4	60		RICKER
	■	NIGHT	4	60		RICKER
SCHUYLKILL EXPRESSWAY,	x	DAY	4	60	50(TT	COLEMAN
PHILA.	○	DAY	6	50		COLEMAN
SHIRLEY HWY, ARLINGTON, VA.	♦	DAY	4	50		BPR
FAIRFAX CO, VA	▼	DAY	4	60	40	BPR
LODGE EXPWY, DETROIT	✱	D & N	6	55	40	MALO^A
FORD EXPWY, DETROIT-MILLER RD.	●	DAY	6	55	40	BPR
LONYO BR.	■	DAY	6	55	40	BPR
TELEGRAPH RD.	▲	DAY	6	65		BPR
HAMMAN RD.	●	DAY	4	65		BPR
BELT RD.	■	DAY	4	65		BPR
DETROIT	●	DAY	6	45		
EDENS EXPWY, CHICAGO-LINCOLN AVE	○	DAY	6	60		
GULF FWY, HOUSTON (ON-RAMPS CLOSED)	□	DAY	6	50	40	KEESE
E-W FREEWAY, HOUSTON	▲	DAY	4	50		✱ KEESE
CALIF. FREEWAYS	⊙	DAY	8	55		(FILM)
NIMITZ FWY, OAKLAND, CALIF	Δ	DAY	6	65		KELL
	▲	NIGHT	6	65		KELL

^A BASED ON 5 MIN EACH HOUR DURING ALL 24 HR

^1 OPTIMUM POINT

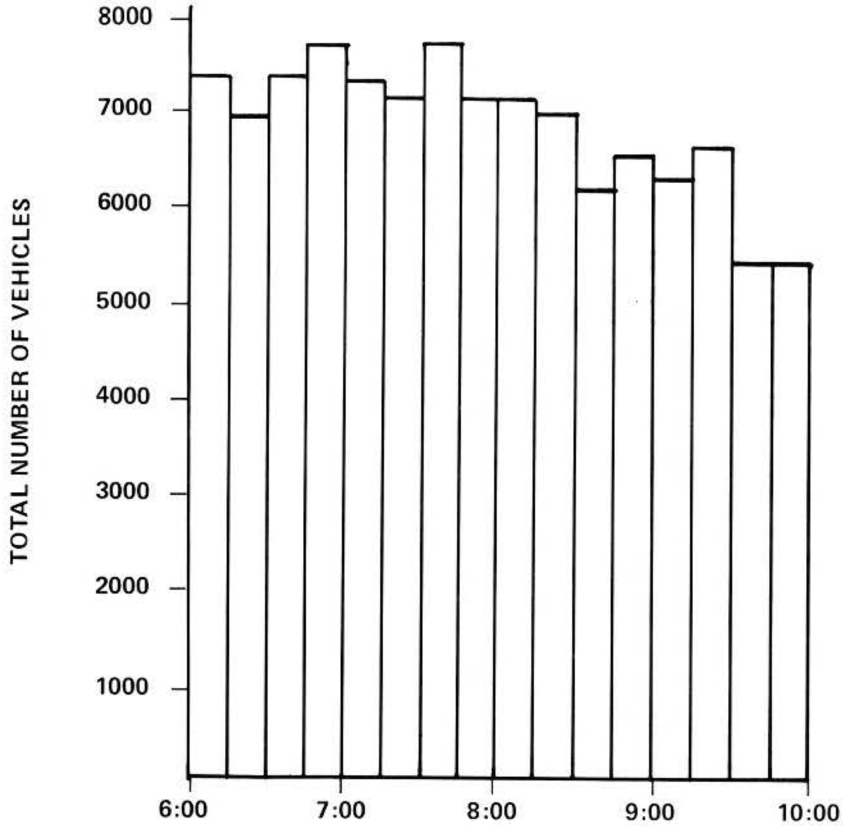
^2 8 LANES

Source: Highway Capacity Manual

Exhibit 6.13

MAINLINE VOLUMES ON THE SAN BERNARDINO FREEWAY

A.M. Peak Period



COUNT AT WARWICK PED. O.C.
W/B A.M. 3/18/81

either being shifted to different departure times or else forgone entirely because of the capacity limitation of the roadway.

In sharp contrast to the mainline usage pattern, the demand curve on the busway shows a very distinct peak. The morning peak is even sharper than the afternoon peak (see Exhibit 6.14).

This sharp peak is probably a good estimate of the demand patterns in this corridor, which would become manifest if there were sufficient roadway capacity available. This implies that there is a very large amount of time-shifting occuring.

It can be seen that busway demand is below the "maximum free-flow volume" of 1400 veh/hr at all times. However, during the quarter-hour beginning at 7:30 AM, the carpool/bus demand (not including violators) is about 325 vehicles, which is equivalent to a flow rate of 1300 vehicles per hour. Therefore, the busway is approaching its maximum free-flow volume only during a short period of time each day. There is substantial excess capacity available during other times, especially during the "tails" (the early and late parts) of the peak period.

This gives rise to the obvious question: would it be possible to significantly improve mainline traffic flow by shifting some volume from the mainline to the busway? To be more precise: if it were possible to "meter" mainline traffic onto the busway, or if the violation rate could be properly manipulated with a suitable enforcement policy, what would be the benefits to mainline flow?

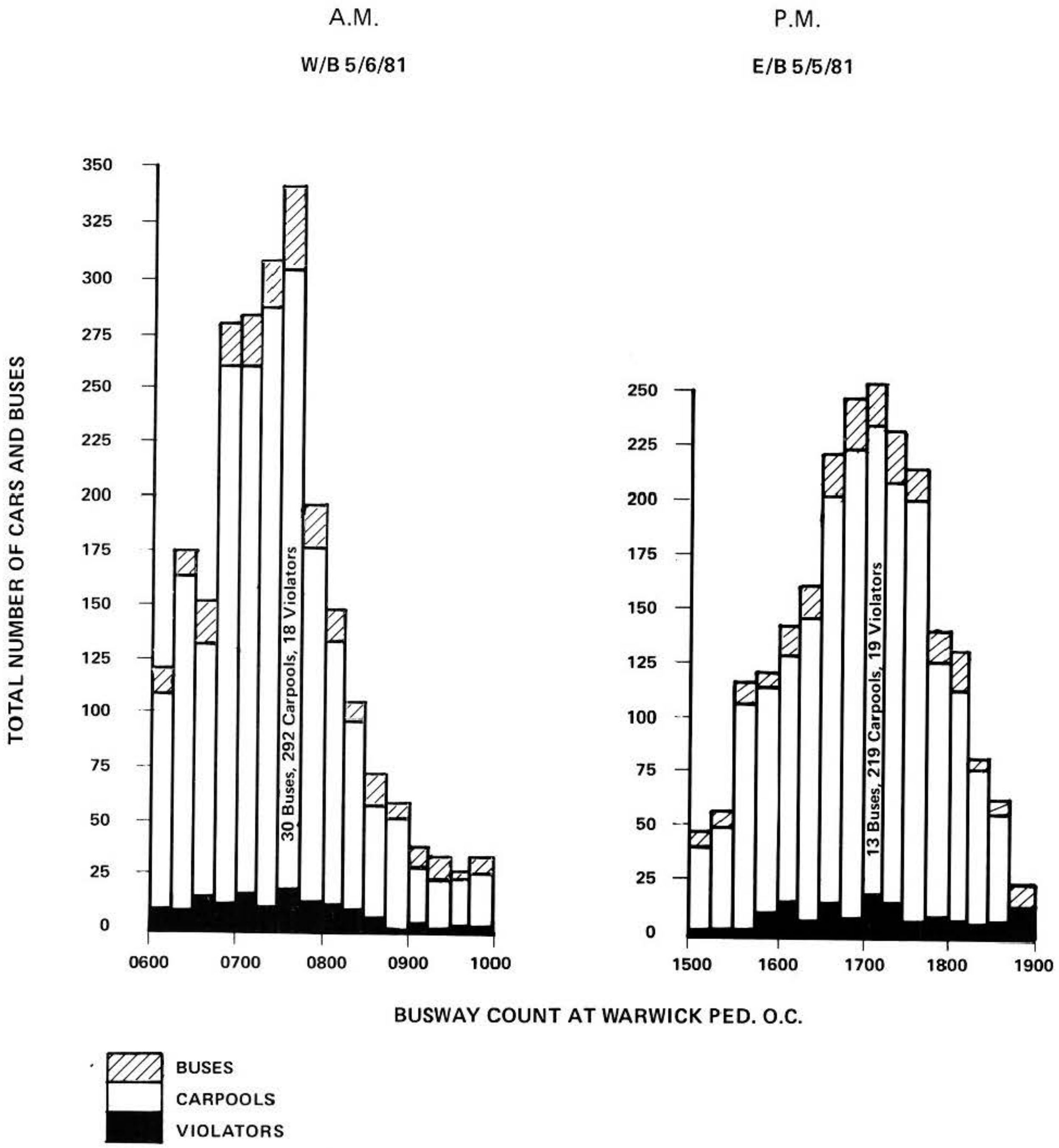
The answer can be found in the two previous plots of mainline and busway volumes. There is available capacity on the busway at all times. But the amount varies at different times of the day, so benefits would also vary.

During the period from 7:00 to 8:00 AM, the difference between current demand and maximum free-flow volume is about 300 vehicles. Thus, about 300 cars could be shifted from mainline to busway without noticeably degrading busway performance. But this would not noticeably improve mainline performance. Because the mainline has 4 lanes, this 300 vehicle reduction would translate to 75 vehicles per lane per hour, or about a 4% drop in volume. Such a drop would produce a noticeable improvement in mainline performance, increasing average speeds by 5 to 10 mph. But because there is substantial latent demand, especially during the peak one-hour period from 7:00 to 8:00 AM, it is quite certain that the 4% drop in mainline volume would be quickly replaced by new motorists. Thus, a new equilibrium condition would soon be established with no overall improvement in mainline conditions.

The situation may be different during the "shoulders" and "tails" of the peak. From 8:00 to 9:00 AM, for example, the bus/carpool demand is about 400 vehicles, so the available capacity is about 1000 vehicles during that hour. This translates to 250 vehicles per hour per mainline lane, or about a 12% decrease. Since it is very difficult to measure latent demand, there is no way of knowing for certain how much of this

Exhibit 6.14

SAN BERNARDINO BUSWAY VOLUMES



12% drop would be replaced and what the new equilibrium conditions would be. But because the mainline is at capacity until 9:00 AM and close to capacity until 10:00 AM, it appears that there is sufficient latent demand to replace most if not all of this 12% shift. From 9:00 to 10:00 AM, the situation is clear-cut and very predictable. There is about 1200 veh/hr excess capacity on the busway and there does not appear to be any latent demand during that hour to replace removed vehicles. However, operating speeds on the mainline from 9:00 to 10:00 AM are usually better than 45 mph, so any further reductions in volume will not produce dramatic improvements in performance.

In summary, mainline performance on the San Bernardino Freeway is never likely to be improved dramatically by increases in the number of violators. Busway performance can be degraded by violators during the hours of 7:00 to 8:00 AM. At other times, however, moderate increases in the number of violator will not affect travel times in the busway.

Summary of Violation Impacts on Traffic Flow. The results from the analysis presented above also apply to the other mainline HOV lanes: Alameda 580 and Marin 101. However, in the case of these two projects, the HOV lane volumes and even the general traffic lane volumes are still well below capacity. Exhibit 6.15 displays the current peak hour volumes on each of the three mainline HOV projects. As can be seen, the lane volumes on Alameda 580 and Marin 101 are much lower than San Bernardino's. Only the general traffic lanes on Alameda 580 are even beginning to approach capacity. The lack of congestion on these facilities supports the conclusions reached in studying the San Bernardino Busway:

- Given the current violation rates, violators are not a problem as far as creating congestion in the HOV lane. Except for a one-hour AM period on the San Bernardino Busway, the violation rates could increase substantially on all the projects without substantially harming flow.

- Violators do not improve general traffic conditions appreciably. During congested periods (30 to 40 mph), latent demand could easily replace the small number of violators drawn off to the carpool lanes. At less congested times, the potential for improvement is minimal.

Enforcement Implications of Results. From the analysis it is clear that a significant number of violations can be tolerated on each of the facilities before service is degraded in the carpool lane. The one exception is the San Bernardino Busway between 7:00 and 8:00 AM in the morning. During this time, a substantial increase in the violation rate above the present level could swiftly lead to congestion problems. Thus, the appropriate enforcement strategy on the San Bernardino Busway is clear during the peak AM period: violation rates should be held at current or lower levels. For the other projects, there is ample room for violations to increase throughout the hours of operation without affecting performance. The maximum tolerable violation rate (from an

Exhibit 6.15

PEAK HOUR TRAFFIC VOLUMES FOR MAINLINE HOV LANE FACILITIES*

Project	Peak Hour	Carpool Lane Volume				General Traffic Volume per Lane (No. Lanes)
		Carpools	Buses	Violators	Total	
Marin 101	4:30 to 5:30 PM	163	72	51	286	930 (3)
Alameda 580	4:30 to 5:30 PM	168	5	60	233	1,500 (2)
San Bernardino Busway	7:00 to 8:00 AM	1,088	84	31	1,203	1,860 (4)

*Based on latest counts

operational standpoint) for an HOV lane is plotted in Exhibit 6.16 for a range of HOV lane carpool and bus volumes. The maximum tolerable rate is defined as the rate that allows the number of violators to increase to the point where total lane flow equals 1400 vehicles an hour. The graph assumes that service in the HOV lane will not be degraded until this flow level is reached and therefore the number of carpools will not change. An acceptable level of lane violation rates from a purely operational point of view is well over 80% for both Marin 101 and Alameda 580 even during the peak traffic hour. During less congested times, the maximum violation rate would be even greater.

Although violation rates of 80% could theoretically be tolerated on some mainline HOV lanes without affecting flow adversely, such violation levels are clearly intolerable from the standpoint of a law enforcement agency. Violation rates as high as 80% would also undoubtedly be unacceptable to most carpool users and the public in general. Even on Alameda 580, where public sentiment runs highly against the lane, most freeway users still feel that the use of the HOV lane by violators is at least a minor problem.

In summary, the "acceptable" violation rate for the San Bernardino Busway is strictly defined by operational considerations to be 16% or less during the peak morning period. During the other times, the violation rate could be greater from an operational standpoint but should realistically be set at 10% or less so that violations do not increase beyond their present level. This limit will prevent the pool of violators from increasing to a point where AM peak period violation rates could get out of control and will also prevent public disgruntlement over HOV lane violators. For the other projects, the suggested acceptable violation rate is the current normal level. Thus, the main goal of the suggested program is to keep violations from increasing to a point where complaints from the public become common and a mass disobedience of the law becomes apparent.

6.3 SUMMARY OF FINDINGS

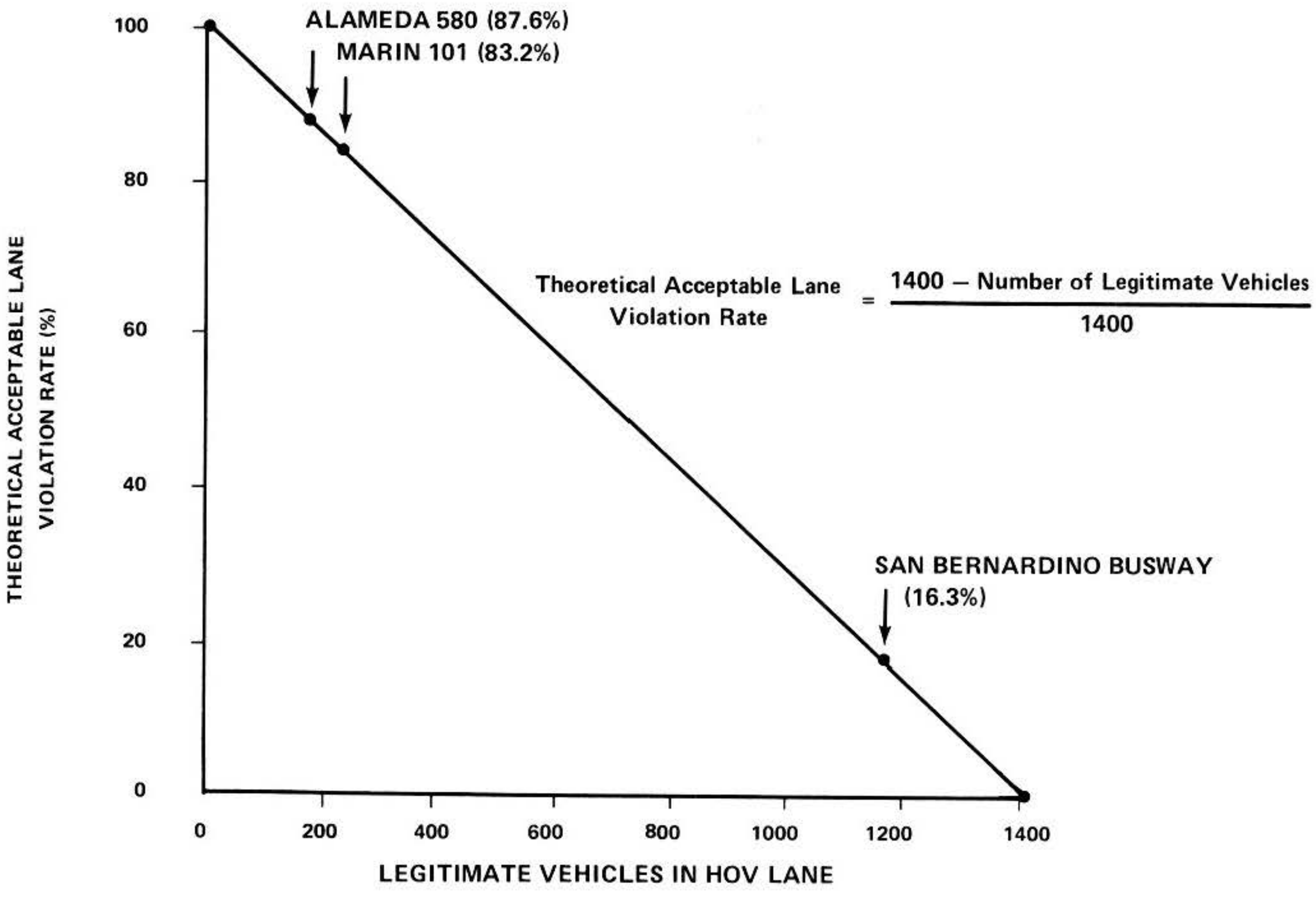
6.3.1 Ramp Meter Bypass Lanes

The Question of Tolerable Violation Rates. This chapter has proposed a cost-effective enforcement program designed to keep violation rates at acceptable levels. Since the question of "tolerable", or "acceptable" violation rates can be viewed from several different aspects, including safety, freeway operations, public attitudes, legal integrity, and practicality, it is worth reviewing the findings of past chapters regarding these topics before summarizing the proposed program.

- Safety. Less than twenty percent of the drivers using ramp bypass lanes illegally do so through maneuvering which presents a direct safety hazard to other drivers. However, there is some statistical evidence that accident levels are significantly higher on ramps with high violation rates (i.e., violation rates over 12%).

Exhibit 6.16

ALLOWABLE VIOLATION RATE* AGAINST CARPOOL LANE OCCUPANCY



*Defined as the violation rate at which carpool lane performance begins to decline.

- Freeway Operations. By using bypass lanes illegally, all violators threaten the time savings, accident relief, and other benefits obtainable through metered ramp control. For any particular freeway, the impact of violations on freeway flow will depend on roadway characteristics, the number of ramps provided with bypass lanes, and the metering strategy selected. A sensitivity analysis of a single freeway, however, suggests that ramp violations can have a disproportionate impact on freeway flow. Violation rates of 20% on the sample freeway brought about a 34% reduction in passenger time savings. Violation rates below 10% had a less pronounced impact.

- Public Attitude. The majority of the public regards ramp violations as a minor problem and tend to overestimate low violation rates and underestimate high violation rates. Drivers are not likely to be sensitive to changes in ramp violation rates below the 6.5% range. Law enforcement agencies should keep an open ear for public complaints about violation rates, however, and respond with special enforcement when such complaints are aired.

- Practicality. On most ramps, it is virtually impossible to drive ramp violation rates significantly below 5%, even with relatively heavy levels of enforcement. These violation rates should definitely be tolerated, and in fact, metering strategies should be designed to accommodate a 5% violation rate.

In the light of these conditions, a proposed enforcement program has been designed with the aim of:

- Reducing violations dramatically on ramps with violation rates over 12% (particularly on ramps with violation rates in excess of 20%).

- Controlling violation rates and achieving further reductions on ramps with violation rates between 6.5 and 12%.

- Maintaining violation levels on low-violation ramps through a program of routine enforcement and a minimum amount of special enforcement.

Proposed Program. to accomplish this, a program of selective enforcement is proposed which combines the annual monitoring of violations with twice-yearly applications of four-week periods of special enforcement on ramps with medium and high violation rates. Ramps with violation rates of 6.5% or lower will receive relatively low levels of special enforcement once a year. Newly opened bypass lanes shall receive the special enforcement attention recommended for ramps with medium and high violations during their first month of operation. Routine enforcement practices will be followed between periods of special enforcement on all ramps.

The proposed program will require the following average commitments of officer time:

RAMP VIOLATION RATE	ROUTINE ENFORCEMENT (Hours/Year)	SPECIAL ENFORCEMENT (Hours/Year)	TOTAL (Hours/Year)
Low (<6.5%)	6	16	22
Medium	7	48	55
High (>12%)	48	96	144

The enforcement levels recommended on ramps with medium and high violation rates are analogous to those which proved effective in reducing violation rates on comparable ramps during the current study. As the proposed enforcement program progresses, it is anticipated that more and more ramps will be shifted into the "low violation" category, where they will require minimum attention.

Program Costs. While routine ramp enforcement activities can easily be accomplished in concert with other patrol duties, special ramp enforcement requires the dedication of one or two officers to a single ramp for the full metering period. The personnel requirements imposed by the special ramp enforcement program may be met either by offering overtime duty to existing personnel, or by adding personnel to the morning and evening shifts. These two options have markedly different cost implications. In the first case, existing officers must be paid an overtime premium. In the second case, new officers must be hired for eight hours per day to accomplish duties which consume, at most, four hours. the combined average cost of special and routine enforcement under each option is listed below for ramps with low, medium, and high violation rates:

AVERAGE ANNUAL OUT-OF-POCKET ENFORCEMENT COST PER RAMP
(SPECIAL AND ROUTINE)

RAMP VIOLATION RATE	Overtime Option	New Personnel
Low (<6.5%)	$502	$729
Medium	$1273	$1955
High (>12%)	$3306	$4669

On the basis of these average rates, the first-year costs of the proposed enforcement program in those CHP Divisions having ramp meter bypass lanes are listed below:

DIVISION	TOTAL ANNUAL ENFORCEMENT COSTS Overtime Option	New Personnel
Golden Gate (San Francisco Metro Area)	$1,775	$2,683
Southern (Los Angeles Metro Area)	$172,205	$252,577
Border (Orange County & San Diego)	$63,474	$92,535

Citation Revenues. Each time a fine is assessed from a cited violator, the dollar amount of the fine is allocated to the treasury of the city or county where the offense occurred. In every county except San Diego, each citation brings considerably more money into the treasury of the local jurisdiction than it costs the CHP to issue and the local courts to process. If senior officer overtime is taken as the basis for computing enforcement costs, the average societal "profit" resulting from special enforcement activities is $15.51 per citation on high violation ramps, $13.00 on medium violation ramps, and $3.39 on low violation ramps. In San Diego, the bail schedule for the 21655.5 occupancy violation is so low ($13.50 per violation), that it does not begin to reflect the cost of special enforcement on the low-violation bypass lanes in that jurisdiction.

Operational Benefits and Costs. The out-of-pocket costs of the proposed enforcement program are roughly commensurate with the societal costs incurred in delays and increased freeway accidents if violations are not controlled. An overview of the average costs and benefits associated with a single metered ramp/bypass lane combination appears below.[9]

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[9] These costs and benefits reflect average values which assume that all ramps have an equivalent impact on freeway flow. This is not the case, and it is possible that a low level of violations on a few critically positioned ramps can negate most of the positive benefits of ramp metering.

AVERAGE BENEFITS AND COSTS PER RAMP
METERED RAMP/BYPASS COMBINATION

<u>INITIAL INVESTMENT</u>
$27,000 (ramp meter)
<u>4,000</u> (bypass lane)
$31,000

<u>AVERAGE ANNUAL COSTS</u>
$1,500 (operations)
3,000 (maintenance)
235 (power)
481 (increased ramp accidents)
$336 to $2,013 (traffic disruption resulting from enforcement)
$502 to $4,669 (out-of-pocket enforcement costs)

<u>AVERAGE ANNUAL BENEFITS</u>
$9,255 (improved freeway travel time)
815 (reduced freeway accidents)
717 (priority entry time savings)
$1,577n (savings per new carpool formed)

<u>Total Annual Costs</u>:

Violation Rate	(Overtime)	(New Personnel)
Low	$6,054	$6,281
Medium	7,495	8,177
High	10,535	11,898

<u>Total Annual Benefits</u>:
$10,787 + $1,577n
(where n = number of new carpools formed)

Even if a bypass lane generates no additional carpools, the average annual benefits from installing a ramp meter and bypass lane comfortably exceed the annual costs of ramp operations and enforcement on all but high-violation ramps. Although the effectiveness of ramp bypass lanes in encouraging the formation of new carpools is not well understood, even a modest degree of success in this area will generate enough benefits to offset both the cost of enforcement and the initial investment in the average bypass lane.

6.3.2 <u>Mainline HOV Lanes</u>

<u>The Question of Tolerable Violation Rates</u>. As in the case of ramp meter bypass lanes, questions of safety, freeway operations, and public attitudes have been explored in attempting to define a "tolerable" violation rate for mainline HOV lanes.

- <u>Safety</u>. Although it is impossible to correlate accident rates with violation rates on any of the mainline projects, the practice of weaving illegally in and out of a mainline lane creates a direct safety hazard. Unsafe weaving has been and should continue to be the primary focus of officers assigned to HOV lane enforcement.

- Freeway Operations. The practical capacity of a mainline HOV lane is estimated to be 1400 vehicles per hour. Except for a one-hour period during the morning peak on the San Bernardino Busway, existing violation rates could increase substantially on all California mainline projects without substantially affecting flow in the carpool lane.

  Violators do not improve general traffic conditions appreciably by leaving the mainline flow to enter the HOV lane. During congested periods, latent demand easily replaces the small number of violators drawn off into the carpool lanes. At less congested times, the potential for improvement is minimal.

- Public Attitudes. Even on Alameda 580, where public sentiment runs heavily against the HOV lane, most freeway users still feel that the use of the HOV lane by violators is at least a minor problem. Drivers tend to overestimate violation rates on most mainline projects.

On the San Bernardino Busway, the "tolerable" violation rate is strictly defined by operational considerations to be 16% or less during the peak morning period. During the other times, the violation rate could be greater from an operational standpoint. Realistically, a tolerable violation rate should be set at 10% or less at all times to keep violations from increasing beyond their present level and prevent the pool of violators from increasing to a point where AM peak period violation rates could hamper Busway operations. For the other projects, the suggested acceptable violation rate is the current normal level. Thus, the main goal of the proposed program is to keep violations from increasing to a point where complaints from the public become common and a mass disobedience of the law becomes apparent.

Proposed Program. The proposed program is summarized below. This program is aimed at maintaining mainline HOV violations at current levels or lower, and represents little change from existing levels on the San Bernardino Busway and San Francisco/Oakland Bay Bridge. On Alameda 580, a small increase in special enforcement is suggested, while Marin 101 could probably be enforced less without incurring adverse affects.

PROPOSED ENFORCEMENT PROGRAM
MAINLINE HOV LANES AND THE SAN FRANCISCO/OAKLAND BAY BRIDGE

	PERSON HOURS/YEAR			
Route	Special Enforcement	Routine Enforcement	Total Hours	Total Cost
Marin 101	4800	negligible	4800	$111,600 (overtime) to $180,000 (new personnel)
Alameda 580	64	384	448	$10,070
San Bernardino Busway	448	1920	2368	$53,328
SF/Oakland Bay Bridge	256	120	376	$8,628

As in the case of ramp meter bypass lanes, CALTRANS should monitor violation rates at least once annually, with San Bernardino Busway rates monitored quarterly.

On Marin 101, routine enforcement is negligible and special enforcement occurs daily at levels that are probably higher than necessary. If future CALTRANS counts show no increase in violations, the number of motorcycle officers assigned to special enforcement in the evening could be cut from four to two.

On Alameda 580, two two-week waves of special enforcement are recommended each year, with one direction of flow enforced during each wave.

On the San Bernardino Busway, two four-week waves of special enforcement are recommended each year. Special enforcement should concentrate on the morning peak, especially during the period between 7:00 and 8:00 AM.

Since short, intense bursts of enforcement appear to be most effective on the San Francisco/Oakland Bay Bridge, four one-week periods of heavy enforcement are proposed each year.

Citation Revenues. On every project except Marin 101, each citation issued during special enforcement brings more money to the treasury of the local jurisdiction than it costs the CHP to issue and the local courts to process. On Marin 101, where the lack of a median strip makes enforcement difficult, citation revenues do not cover the full cost of a new officer especially hired for HOV lane enforcement.

APPENDIX A

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REFERENCES

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NOTE: An extensive bibliography of previous research regarding HOV lane enforcement and California TSM projects may be found in the Study Design (Reference 1).

APPENDIX B

GLOSSARY

GLOSSARY

Apprehension Rate	Citations issued per day/violators per day.
Area Characteristics	Socioeconomic, demographic, and geographic statistics related to the area in which TSM project is located.
Citation Rate	Number of citations issued over period of time on TSM project.
Duration of Enforcement	Period (days) over which a special enforcement program is carried out.
Enforcement History	History of previous enforcement programs on HOV projects, including their duration, frequency of coverage, and resulting violation rates.
Enforcement Visibility	Applied to metered ramps. Ability to see a CHP officer, if present (or determine that no unit is present). Metered ramps with or without bypass lanes can be categorized into three groups of enforcement visibility: those where an enforcement unit's presence is always determinable; those where it is never known; and those where it is visible only at a certain point on the ramp (thus termed, queue-dependent).
Expected Sightings	Average number of violators a non-violator in the metered queue or general traffic lanes is likely to see pass by. For mainline HOV lanes this is an empirical observation; for ramps, an attempt will be made to develop a formula relating queue lengths and violation rates to empirical data.
Follow-through Violation	For metered ramps without bypasses: $= \frac{\text{\# of cars following another car through meter lights}}{\text{total \# cars using ramp}}$
Frequency of Coverage	Number of times a CHP unit patrols a TSM project (days/month).
Geometrics	Physical characteristics of project, such as shape of ramp (e.g., diamond, hook, loop) placement of meter, placement of HOV lane, existence of shoulder/median strip, separation of HOV lane.
HOV	High-occupancy vehicle.
HOVL	High-occupancy vehicle lane.

Historical Citation Rate	Number (and trends) of citations given over projects history (a series of data points).
Historical Deployment	Historical manpower level assigned to ramp during special enforcement projects.
Historical Ramp Violation Rate	Rate (and trends) of ramp violations over time (a series of data points).
Lane Violation Rate	For metered ramps with bypasses: $= \frac{\text{\# single occupancy cars in carpool lane}}{\text{total \# cars in carpool lane}}$ For mainline HOVL's: $= \frac{\text{\# cars carrying less than 3 people in HOVL}}{\text{total \# cars in HOV lane}}$ In general: $= \frac{\text{\# of vehicles in special lane not meeting lane occupancy requirements}}{\text{total \# cars in special lane}}$
Length of Stay	Amount of time (minutes) CHP unit is enforcing a TSM project during day of enforcement period.
Meter Violation Rates	Red violation rate + shoulder violation rate + follow-through violation rate.
% Regular Users	Percentage of vehicles using TSM project regularly.
% Repeat Violators	Percentage of drivers repeatedly violating HOV restrictions.
Project Life	Time since project's initiation (months).
Queue Delay	Average queue lengths and delay in metered lane of ramp.
RM	Ramp metering.
RMB	Ramp meter bypass lanes.
Ramp Violation Rate	For metered ramps with bypasses: $= \frac{\text{\# single occupany cars in carpool lane}}{\text{total \# cars on ramp}}$
Red Violation Rate	For metered ramps without bypasses: $= \frac{\text{\# cars running red meter light}}{\text{total \# cars using ramp}}$
Residual Enforcement Impact	Length of time after employment activity until average HOVL violation rate equals or exceeds pre-enforcement level.

Shoulder Violation Rate	For metered ramps without bypasses: $= \frac{\text{\# cars bypassing meter queue on shoulder}}{\text{total \# cars using ramp}}$
Start-Up Strategies	Refers to enforcement strategy employed at initiation of HOV project. Types include a grace period of handing out no citations to violators, and either giving or not giving warnings, a regular enforcement scheme, or an intensive enforcement scheme. Start-up strategies may or may not be advertised.
Traffic volume	Number of cars on HOVL; on lanes adjacent to HOVL.
TSM	Transportation Systems Management.
Vantage Point	Enforcement units' view of violators from refuge area.
Violation Rate	Term used interchangeably with HOV Lane Violation Rate on projects other than ramps.
Visibility Distance	Distance from ramp meter at which presence or absence of enforcement unit can be detected.

APPENDIX C

RAMP
CLASSIFICATION
MATRIX

CLASSIFICATION OF RAMP BYPASS LANES
BY ENFORCEMENT VISIBILITY AND VIOLATION RATES
(A SAMPLE OF 49 LOS ANGELES RAMPS)

RAMP VIOLATION RATES	ENFORCEMENT VISIBILITY		
	VISIBLE	QUEUE-DEPENDENT	NOT VISIBLE
HIGH	AM Florence, LA 11 AM Wilshire, LA 405 PM Carson, LA 605	AM Firestone, LA 405 AM Venice, LA 10▲ PM Western WB, LA 10▲ PM Olympic/Pico, LA 405 PM Moraga, LA 405▲ PM Manchester, LA 405**•	AM Bundy, LA 10▲ AM Vernon, LA 11 AM Manchester EB, LA 11 AM Western EB, LA 10 AM National, LA 10▲ PM Lakewood SB, LA 405 PM Crenshaw, LA 10▲ AM Century WB, LA 405**•
MEDIUM	AM Lakewood NB, LA 91 PM Pasadena, LA 5▲ PM Spring, LA 405 PM Century, LA 7•	AM Manning, LA 10 AM Orangethorpe WB, OR 91* AM Coldwater Canyon▲ AM Burbank, LA 170 PM Whittier EB, LA 605 PM Century, LA 405** PM Los Feliz, LA 5 PM Hawthorne, LA 405**• PM Laurel Canyon, LA 101•	AM Tuxford, LA 5 AM Imperial WB, LA 405** AM Woodman, LA 101 PM South Street, LA 605 PM Orangethorpe EB, OR 91* PM Artesia, LA 405** AM Century EB, LA 405**• PM Slauson, LA 605•
LOW	AM Whittier WB, LA 605 PM Hollywood Way, LA 5 PM Beverly, LA 605 PM Imperical Hwy, LA 605 PM Normandie, LA 405** PM Alondra, LA 605•	AM Imperial EB, LA 405** PM Inglewood SB, LA 405**	AM Katella, OR 605 AM Burbank, LA 5 PM Colorado, LA 5 AM El Segundo, LA 405**

Notes:

Violation Rate Division: High = > 12%; Low = < 6.5%

*Indicates ramps with special striping

▲Indicates ramps in which some entering vehicles can be "trapped" in carpool lane if queue exceeds ramp storage capacity

•Indicates ramps with routine enforcement only

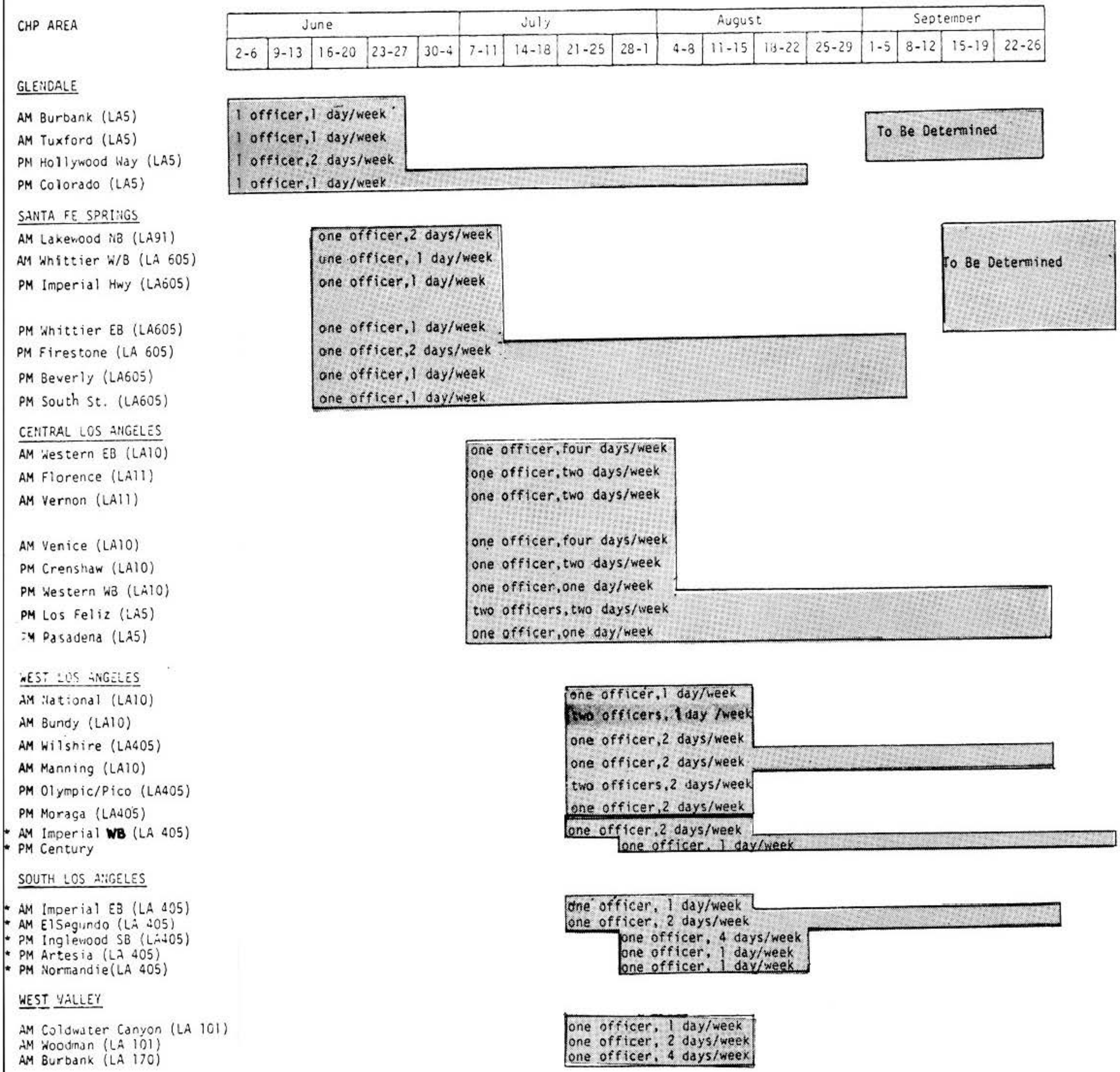
**Indicates ramps which were opened recently (July 1980)

APPENDIX D

SCHEDULE
OF
SPECIAL ENFORCEMENT ACTIVITIES

- CHP Southern Division
- CHP Border Division

FIRST WAVE OF SPECIAL RAMP ENFORCEMENT
CHP SOUTHERN DIVISION



CHP AREA	
GLENDALE	
AM Burbank (LA5)	1 officer,1 day/week
AM Tuxford (LA5)	1 officer,1 day/week
PM Hollywood Way (LA5)	1 officer,2 days/week
PM Colorado (LA5)	1 officer,1 day/week
	To Be Determined
SANTA FE SPRINGS	
AM Lakewood NB (LA91)	one officer,2 days/week
AM Whittier W/B (LA 605)	one officer, 1 day/week
PM Imperial Hwy (LA605)	one officer,1 day/week
PM Whittier EB (LA605)	one officer,1 day/week
PM Firestone (LA 605)	one officer,2 days/week
PM Beverly (LA605)	one officer,1 day/week
PM South St. (LA605)	one officer,1 day/week
	To Be Determined
CENTRAL LOS ANGELES	
AM Western EB (LA10)	one officer,four days/week
AM Florence (LA11)	one officer,two days/week
AM Vernon (LA11)	one officer,two days/week
AM Venice (LA10)	one officer,four days/week
PM Crenshaw (LA10)	one officer,two days/week
PM Western WB (LA10)	one officer,one day/week
PM Los Feliz (LA5)	two officers,two days/week
PM Pasadena (LA5)	one officer,one day/week
WEST LOS ANGELES	
AM National (LA10)	one officer,1 day/week
AM Bundy (LA10)	two officers, 1day /week
AM Wilshire (LA405)	one officer,2 days/week
AM Manning (LA10)	one officer,2 days/week
PM Olympic/Pico (LA405)	two officers,2 days/week
PM Moraga (LA405)	one officer,2 days/week
* AM Imperial **WB** (LA 405)	one officer,2 days/week
* PM Century	one officer, 1 day/week
SOUTH LOS ANGELES	
* AM Imperial EB (LA 405)	one officer, 1 day/week
* AM ElSegundo (LA 405)	one officer, 2 days/week
* PM Inglewood SB (LA405)	one officer, 4 days/week
* PM Artesia (LA 405)	one officer, 1 day/week
* PM Normandie(LA 405)	one officer, 1 day/week
WEST VALLEY	
AM Coldwater Canyon (LA 101)	one officer, 1 day/week
AM Woodman (LA 101)	one officer, 2 days/week
AM Burbank (LA 170)	one officer, 4 days/week

▨ Special enforcement as indicated on specified ramp bypass land

Routine enforcement levels (business as usual) at other times

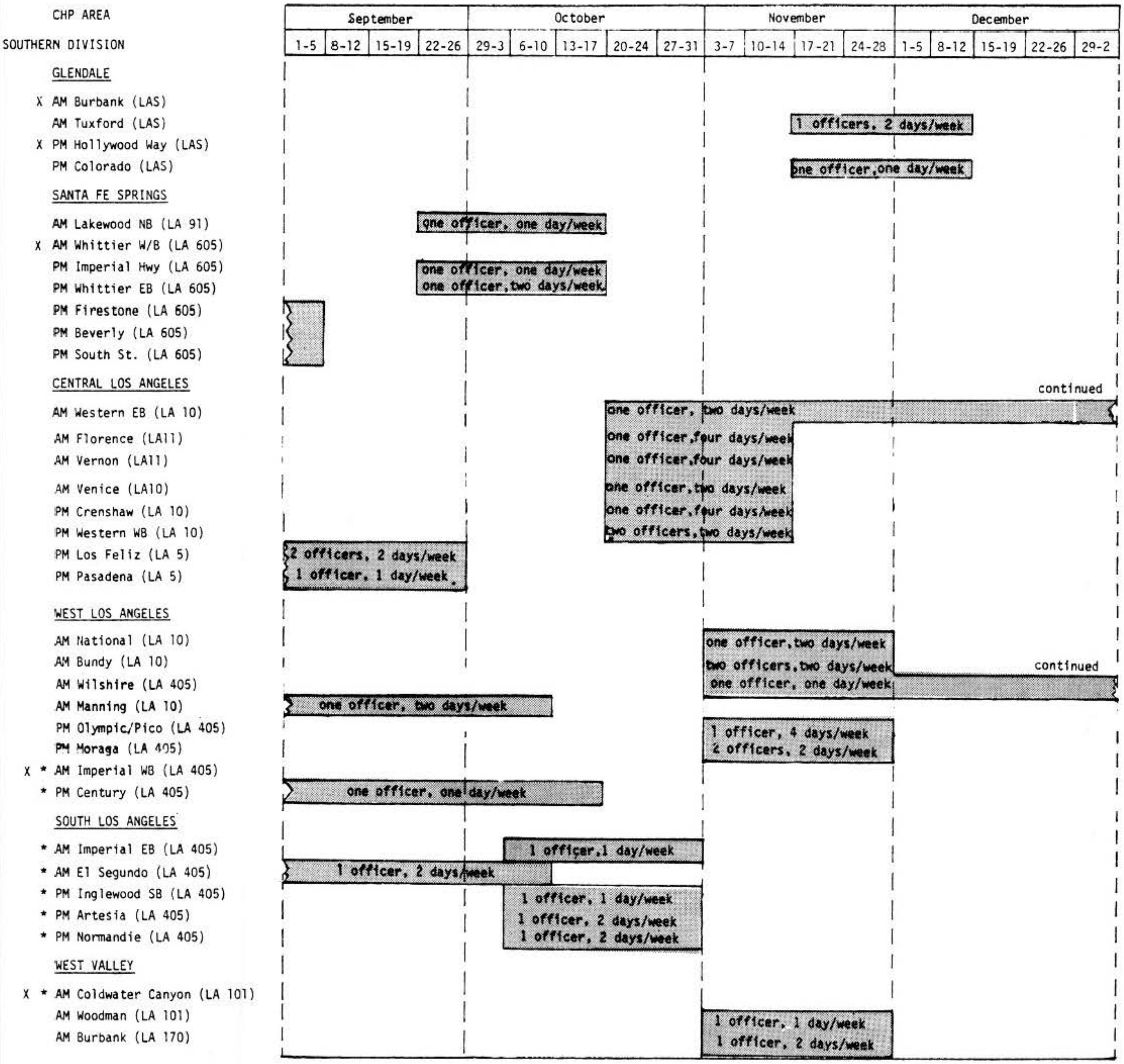
* New Bypass Lanes

FIRST WAVE OF SPECIAL RAMP ENFORCEMENT: CHP BORDER DIVISION

	May				June				July					August			
CHP AREA	5-9	12-16	19-23	26-30	2-6	9-13	16-20	23-27	30-4	7-11	14-18	21-25	28 Aug 1	4-8	11-15	18-22	25-29
EL CAJON																	
AM Spring St.			one officer,one day/week														
AM Rt. 94 - Rt. 94			one officer,two days/week														
AM College Grove			one officer,one day every second week				one officer,one day every second week										
SAN DIEGO																	
AM I-805 - Rt. 94					one officer,two days/week												
AM I-15 - Rt. 94					one officer,one day/week				one officer,one/day week				one officer,one day/week				
AM 49th St. - Rt. 94					one officer,one day every second week				one officer,one day every second week								
AM Kelton (Routine enforcement only)																	
WESTMINSTER																	
AM Katella (OR 605)					one officer,two days/week												
PM Lakewood SB (LA 405)					one officer,four days/week												
PM Spring (LA405)					one officer,two days/week												
SANTA ANA																	
AM Orangethorpe (OR 91)							one officer,two days/week										
PM Orangethorpe (OR 91)							one officer,two days/week										

▨ : Special enforcement as indicated on specified ramp bypass lane
Routine enforcement levels (business as usual) at other times

SECOND WAVE OF SPECIAL RAMP ENFORCEMENT ACTIVITIES: CHP SOUTHERN DIVISION



▨ Special enforcement as indicated on specified ramp bypass lane

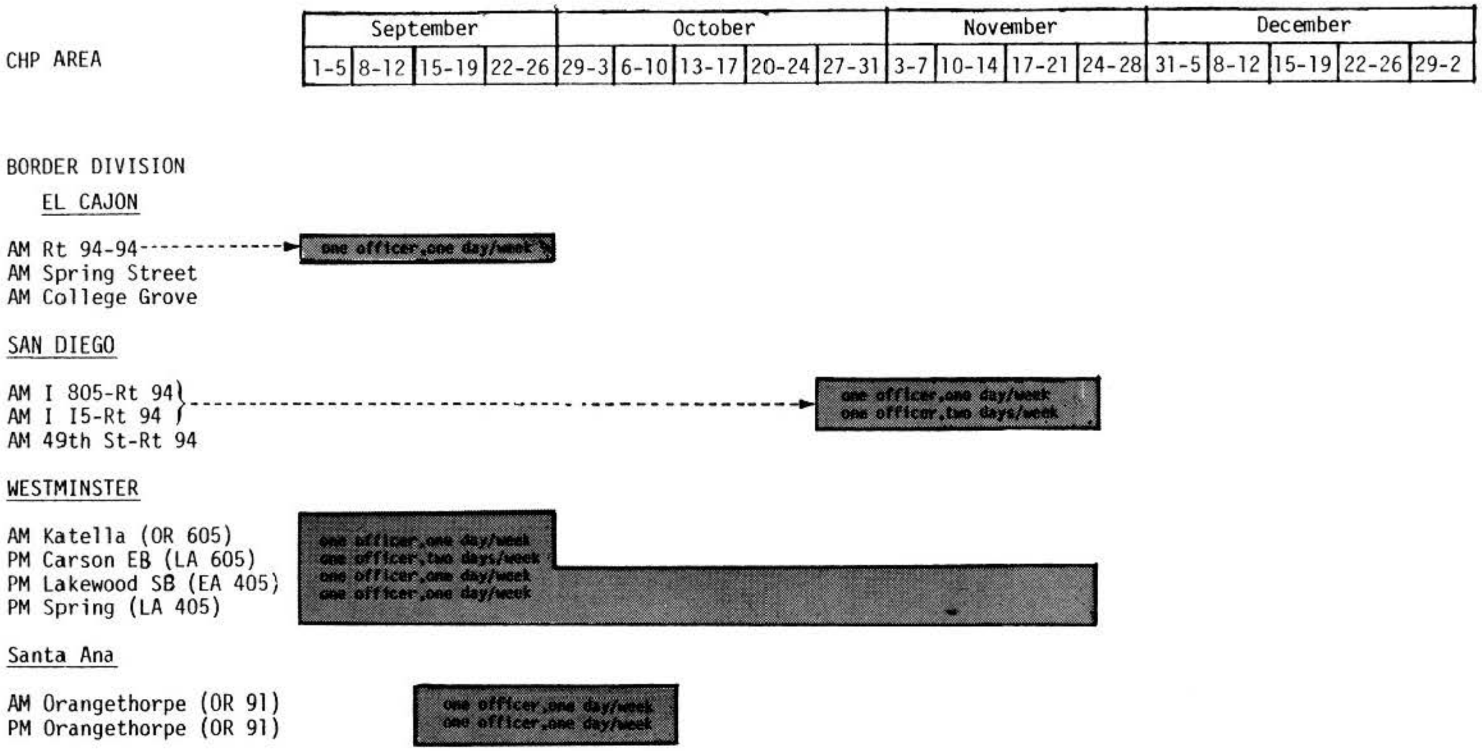
Routine enforcement levels (business as usual) at other times

* New Bypass Lanes

X Ramps omitted from second enforcement wave

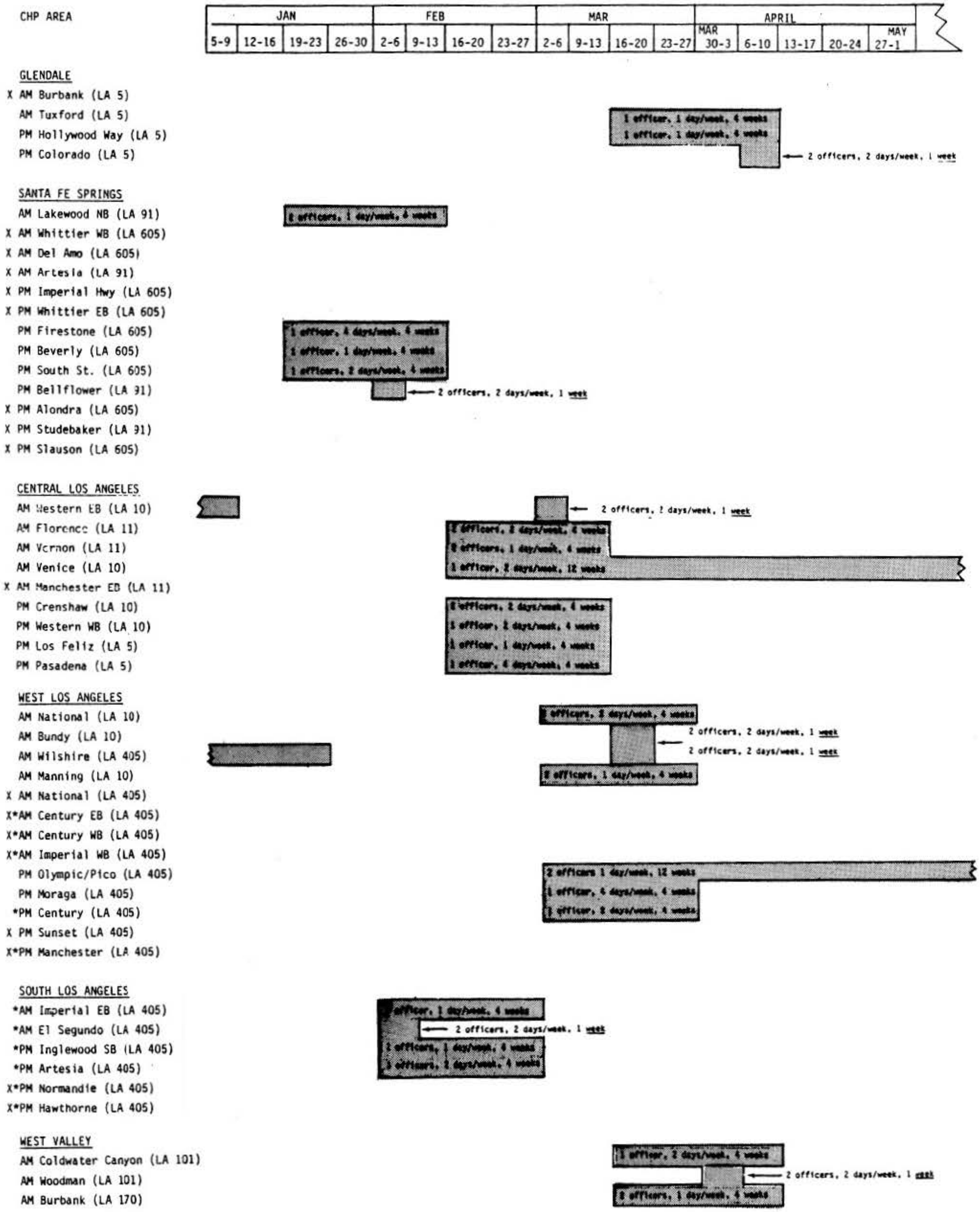
SECOND WAVE OF SPECIAL RAMP ENFORCEMENT ACTIVITIES: CHP BORDER DIVISION

September-December 1980



Legend ▨	Special enforcement as indicated on specified ramp bypass lane
	Routine enforcement levels (business as usual) at other times

THIRD WAVE OF SPECIAL RAMP ENFORCEMENT ACTIVITIES: CHP SOUTHERN DIVISION

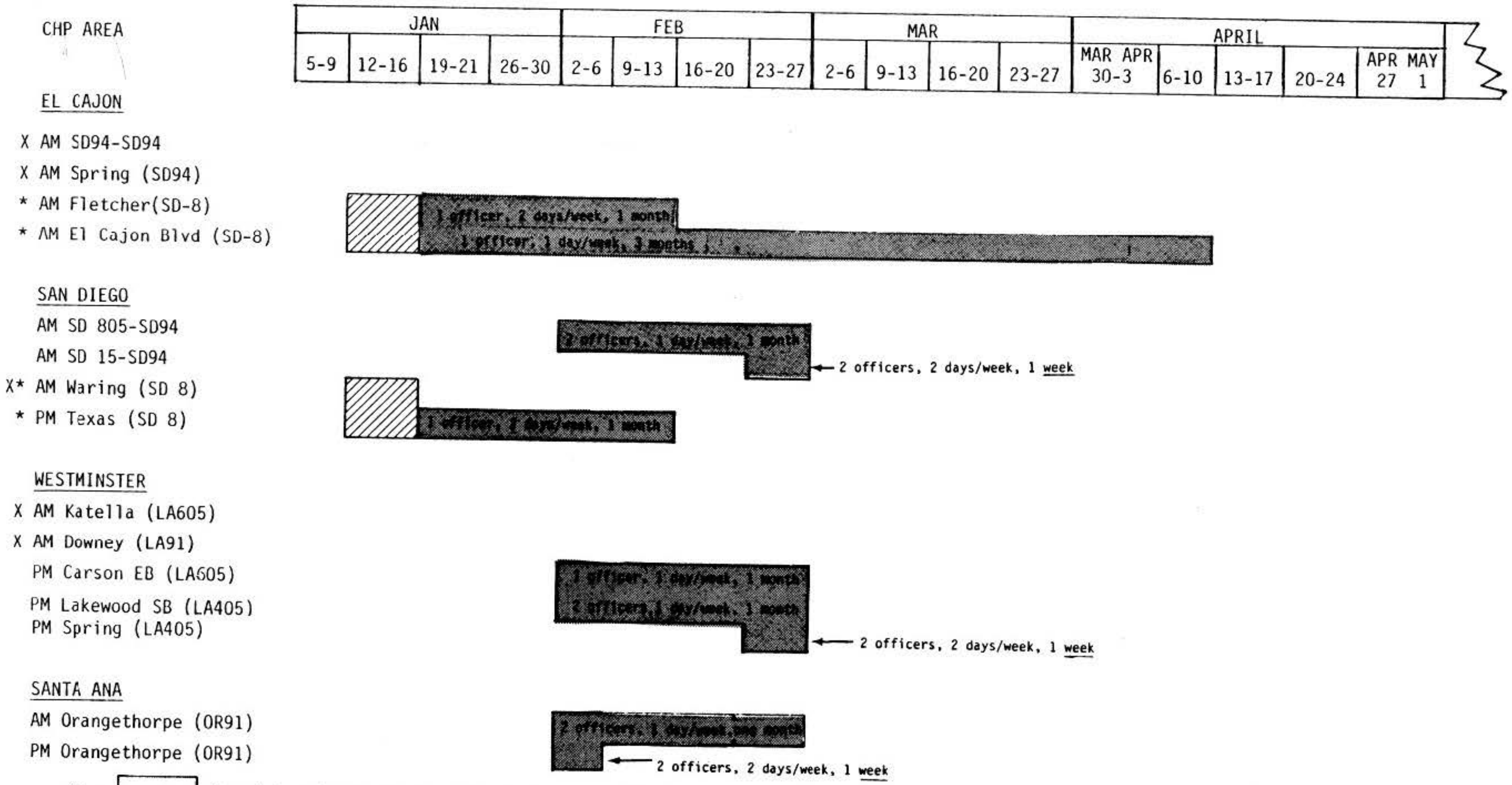


Key: ▨ Special enforcement as indicated on specified ramp bypass lane.
Routine enforcement levels at other times.

* New Bypass Lanes.

X Ramps omitted from third enforcement wave.

THIRD WAVE OF SPECIAL RAMP ENFORCEMENT ACTIVITIES:
CHP BORDER DIVISION



Key: ☐ Special enforcement as indicated on specified ramp bypass lane.
▨ Full-time surveillance by one officer during opening week on new ramps.
* New bypass lanes (assumed opening date Jan 12, if ramp openings are delayed, delay indicated enforcement accordingly).
X Ramps omitted from third enforcement wave.

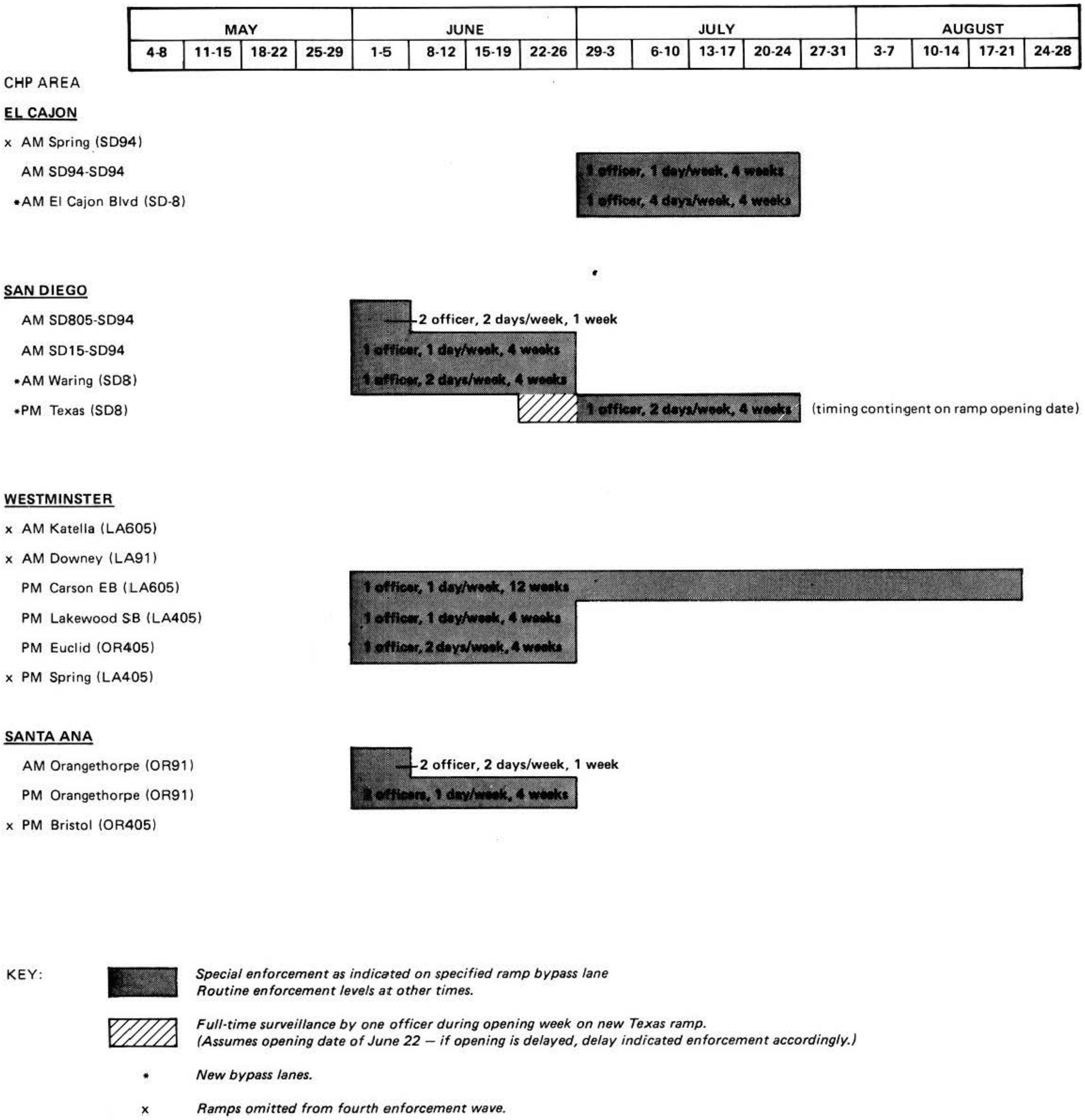
FOURTH WAVE OF SPECIAL RAMP ENFORCEMENT ACTIVITIES
CHP SOUTHERN DIVISION

	MAY				JUNE				JULY					AUGUST			
CHP AREA	4-8	11-15	18-22	25-29	1-5	8-12	15-19	22-26	29-3	6-10	13-17	20-24	27-31	3-7	10-14	17-21	24-28
GLENDALE																	
AM Burbank (LA5)											1 officer, 1 day/week, 4 weeks						
AM Tuxford (LA5)											1 officer, 4 days/week, 4 weeks						
x PM Hollywood Way (LA5)																	
x PM Colorado (LA5)																	
SANTA FE SPRINGS																	
AM Lakewood NB (LA91)			1 officer, 2 days/week, 12 weeks														
AM Firestone (LA605)			1 officer, 4 days/week, 4 weeks														
AM Whittier WB (LA605)			1 officer, 1 day/week, 4 weeks														
x AM Del Amo (LA605)																	
x AM Artesia (LA91)																	
x PM Imperial Hwy (LA605)																	
PM Whittier EB (LA605)			1 officer, 4 days/week, 4 weeks														
PM Bellflower (LA91)			1 officer, 2 days/week, 4 weeks														
PM South St. (LA605)						2 officers, 2 days/week, 1 week											
x PM Beverly (LA605)																	
x PM Alondra (LA605)																	
x PM Studebaker (LA91)																	
x PM Slauson (LA605)																	
CENTRAL LOS ANGELES																	
AM Western EB (LA10)							1 officer, 4 days/week, 4 weeks										
AM Florence (LA11)							2 officers, 2 days/week, 1 week										
AM Vernon (LA11)							2 officers, 2 days/week, 1 week										
AM Manchester EB (LA11)					1 officer, 2 days/week, 12 weeks												
x AM Venice (LA10)																	
PM Crenshaw (LA10)										2 officers, 2 days/week, 1 week							
PM Western WB (LA10)										2 officers, 2 days/week, 1 week							
PM Los Feliz (LA5)							2 officers, 2 days/week, 4 weeks										
x PM Pasadena (LA5)																	
WEST LOS ANGELES																	
AM National (LA10)									1 officer, 2 days/week, 4 weeks								
AM Bundy (LA10)									2 officers, 1 day/week, 4 weeks								
AM Wilshire (LA405)									2 officers, 1 day/week, 4 weeks								
AM Manning (LA10)									1 officer, 2 days/week, 4 weeks								
AM National (LA405)									2 officers, 2 days/week, 1 week								
x•AM Century EB (LA405)																	
x•AM Century WB (LA405)																	
x•AM Imperial WB (LA405)																	
PM Olympic/Pico (LA405)									2 officers, 2 days/week, 1 week								
PM Moraga (LA405)									1 officer, 2 days/week, 4 weeks								
•PM Century (LA405)									1 officer, 1 day/week, 4 weeks								
x PM Sunset (LA405)																	
x•PM Manchester (LA405)																	
SOUTH LOS ANGELES																	
•AM Imperial EB (LA405)					2 officers, 2 days/week, 1 week												
•AM El Segundo (LA405)					1 officer, 4 days/week, 4 weeks												
x•PM Inglewood SB (LA405)																	
•PM Artesia (LA405)					2 officers, 2 days/week, 4 weeks												
•PM Normandie (LA405)					1 officer, 1 day/week, 4 weeks												
x•PM Hawthorne (LA405)																	
WEST VALLEY																	
AM Coldwater Canyon (LA101)											2 officers, 2 days/week, 1 week						
AM Woodman (LA101)											1 officer, 1 day/week, 4 weeks						
AM Burbank (LA170)											2 officers, 2 days/week, 1 week						

KEY: ▨ *Special enforcement as indicated on specified ramp bypass lane. Routine enforcement at other times.*

- • *New bypass lanes.*
- x *Ramps omitted from fourth enforcement wave.*

FOURTH WAVE OF SPECIAL RAMP ENFORCEMENT ACTIVITIES
CHP BORDER DIVISION



APPENDIX E

SUMMARIES
OF
RAMP VIOLATION RATES

CHP SOUTHERN DIVISION

- Glendale
- Santa Fe Springs
- Central Los Angeles
- West Los Angeles
- South Los Angeles
- West Valley

CHP BORDER DIVISION

- El Cajon
- San Diego
- Westminster
- Santa Ana

CHP AREA: GLENDALE

AM/PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT			POST — ENFORCEMENT								
			Month 1	Month 2	Month 3	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
AM BURBANK, LA 5	NV													
First Wave	1C, 1D, 12W	3.8	2.0											
Second Wave	ROUTINE													
Third Wave	ROUTINE													
Fourth Wave	1C, 1D, 4W	2.5	5.0			3.8	2.6	5.5	2.0		2.6			
AM TUXFORD, LA5	NV													
First Wave	1C, 1D, 12W	6.8	6.5	4.3						5.0		8.5		5.3
Second Wave	1C, 2D, 4W	6.9	6.5			7.1				5.9				7.2
Third Wave	1C, ½D, 4W	6.2	6.8			5.6	3.3		6.6			4.0		
Fourth Wave	1C, 4D, 4W	4.9	2.0			3.7	6.1	2.3	3.3					5.3
PM HOLLYWOOD WAY, LA5	V													
First Wave	1C, 2D, 12W	3.5	2.1	2.1								2.7		
Second Wave	ROUTINE													2.2
Third Wave	1C, 1D, 4W	2.4	2.1			1.3	1.2		2.7			1.9		
Fourth Wave	ROUTINE	2.2							2.0				2.8	
PM COLORADO, LA5	NV													
First Wave	1C, 1D, 12W	2.4	1.8	2.0	3.3			2.7		5.7		1.7		2.0
Second Wave	1C, 1D, 4W	2.8	1.7			4.1			3.5				2.7	
Third Wave	2C, 2D, 1W	3.4	1.7			3.0	2.7	2.7		1.8				
Fourth Wave	ROUTINE	2.5						3.4					2.9	
First Wave														
Second Wave														
Third Wave														
Fourth Wave														

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W = Weeks of Enforcement

CHP AREA: SANTA FE SPRINGS

AM / PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT Month 1	Month 2	Month 3	POST — ENFORCEMENT Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
AM LAKEWOOD, LA 91	V													
First Wave	1C, 1D, 4W	7.6	5.6			4.5	4.4	4.7	4.1				5.1	
Second Wave	1C, 1D, 4W	4.6						6.1		5.9				5.4 4.2
Third Wave	2C, 1D, 4W	5.4	5.1			3.9						3.3		4.3 4.3
Fourth Wave	1C, 2D, 12W	4.0	3.3	3.0	3.6	2.3	2.1	2.1	4.4					
AM FIRESTONE, LA605	QD													
First Wave	1C, 2D, 12W		10.9	10.4 9.6	11.5 6.4	7.3	6.6		7.2				10.1	
Second Wave	ROUTINE													7.6
Third Wave	ROUTINE	7.6	12.8			9.7	12.1	9.2		12.5				
Fourth Wave	1C, 4D, 4W	11.3	7.7			7.9	6.1	7.5	9.4		10.9		10.2	9.1
AM WHITTIER WB, LA605	V													
First Wave	1C, 1D, 4W	4.0	2.3			2.1	1.1	3.2	1.0				3.0	
Second Wave	ROUTINE										1.8		1.9	
Third Wave	ROUTINE												1.6	3.0 4.1
Fourth Wave	1C, 1 D, 4W	2.9	1.9			2.8	2.6	2.7	3.2		2.5		3.1	2.5
PM WHITTIER EB, LA605	QD													
First Wave	1C, 1D, 4W	8.1	6.4			6.1	5.3	5.6	7.2				5.7	
Second Wave	1C, 2D, 4W	7.0	7.9				8.1		6.6		6.5		5.6	
Third Wave	ROUTINE					2.8								
Fourth Wave	1C, 4D, 4W	4.9	2.8			3.5	4.0	4.8	6.5		3.7		6.1	4.7
PM BELLFLOWER, LA91														
First Wave	ROUTINE													
Second Wave	ROUTINE												6.4	8.4 7.3
Third Wave	2C 2 D, 1W	7.8	4.1			6.9							4.8	5.9 1.9
Fourth Wave	1C, 2D, 4W	5.9	3.5			4.8	5.6	4.3	4.1		6.5		4.3	4.3

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CHP AREA: SANTA FE SPRINGS

AM/PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT Month 1	Month 2	Month 3	POST — ENFORCEMENT Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
PM SOUTH ST., LA605	NV													
First Wave	1C,1D,12W	10.7	7.8 9.3	4.4	3.8	8.6	7.7		3.5					
Second Wave	ROUTINE													4.8
Third Wave	1C,2D,4W	4.8	3.4			3.6		3.1		3.6		4.0		4.1
Fourth Wave	2C,2D,1W	3.7	4.6			3.3	5.7			3.7	2.6			2.3
AM DEL AMO, LA605														
First Wave	ROUTINE	9.2												
Second Wave	ROUTINE										4.0			
Third Wave	ROUTINE		5.0			3.9								6.6
Fourth Wave	ROUTINE	4.9							3.7					5.0 5.4
PM IMPERIAL HWY, LA605	V													
First Wave	1C,1D,4W	3.8	4.1			4.7	2.7	3.0	3.7					
Second Wave	1C,½D,4W	3.4	6.1				4.1		4.0		3.6		3.3	
Third Wave	ROUTINE					2.8								
Fourth Wave	ROUTINE	3.7					5.5					2.7		5.7
PM BEVERLY, LA605	V													
First Wave	1C,1D,12W	3.6	4.4 2.3	2.9	2.1	5.8	2.0					2.2		
Second Wave	ROUTINE													1.1
Third Wave	1C,1D,4W	2.8	2.1			2.1	2.6	4.4				4.1		5.8
Fourth Wave	ROUTINE	3.7												1.4
PM ALONDRA, LA605	V													
First Wave	ROUTINE	6.4												
Second Wave	ROUTINE											4.2		
Third Wave	ROUTINE		4.2			5.5								4.4
Fourth Wave	ROUTINE	4.6							5.0					4.6

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CHP AREA: SANTA FE SPRINGS

AM/PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT			POST — ENFORCEMENT								
			Month 1	Month 2	Month 3	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
PM STUDEBAKER, LA91														
First Wave	ROUTINE	6.5												
Second Wave	ROUTINE										6.5	13.8	4.8	
Third Wave	ROUTINE										4.0	8.8	4.5	
Fourth Wave	ROUTINE						4.7							8.7
First Wave														
Second Wave														
Third Wave														
Fourth Wave														
First Wave														
Second Wave														
Third Wave														
Fourth Wave														
First Wave														
Second Wave														
Third Wave														
Fourth Wave														
First Wave														
Second Wave														
Third Wave														
Fourth Wave														

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CHP AREA: CENTRAL LOS ANGELES

AM/PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT			POST — ENFORCEMENT								
			Month 1	Month 2	Month 3	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
AM WESTERN EB, LA10	NV													
First Wave	1C, 4D, 4W	20.1	5.8			7.3		7.0	14.5	9.8	12.0			13.1
Second Wave	1C, 1D, 12W	12.6	8.0		6.0			9.5		8.2				
Third Wave	2C, 2D, 1W	8.9				9.4						11.9		11.1
Fourth Wave	1C, 4D, 4W	10.8	4.6			5.8	4.5	5.5	11.9		9.9		8.8	
AM FLORENCE, LA11	V													
First Wave	1C, 2D, 4W	31.1	22.2			24.7	17.7	24.0	21.4				28.6	26.5
Second Wave	1C, 4D, 4W	27.6	16.3						18.4	18.3			18.3	20.7
Third Wave	2C, 2D, 4W	19.5	11.5			17.8				16.5		18.1	20.6	18.7 16.8
Fourth Wave	2C, 2D, 1W	18.1	14.2			18.0	18.7	24.0	16.6	26.4		17.2		17.7
AM VERNON, LA11	NV													
First Wave	1C, 2D, 4W	19.5	11.2			12.8	13.0	13.2	12.6				18.3	17.1
Second Wave	1C, 4D, 4W	17.7	10.0						9.9	10.2			8.9	14.7
Third Wave	2C, 1D, 4W	14.7							15.1		13.3		17.3	15.2
Fourth Wave	2C, 2D, 1W	15.1	8.9			8.8	12.9	11.9	16.8	11.6				9.9
AM MANCHESTER, LA11	NV													
First Wave	1C, 1D, 4W	21.6									15.3		15.9	
Second Wave	ROUTINE													
Third Wave	ROUTINE													17.3
Fourth Wave	1C, 2D, 12W	17.3	19.9	8.5	8.9	7.4	12.2			9.4	7.9			
PM CRENSHAW, LA10	NV													
First Wave	1C, 2D, 4W	31.7	15.8			21.1				23.9	27.0	22.8		18.9
Second Wave	1C, 4D, 4W	20.7	24.0						24.9	20.8			25.7	27.1
Third Wave	2C, 2D, 4W	24.5	13.4						20.2		22.4		16.1	20.7
Fourth Wave	2C, 2D, 1W	19.2	11.9			16.5	18.6	19.4	17.0					23.2

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CHP AREA: CENTRAL LOS ANGELES

AM/PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT			POST — ENFORCEMENT								
			Month 1	Month 2	Month 3	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
AM VENICE, LA10	QD													
First Wave	1C,4D,4W	13.8	7.0			7.7								11.5
Second Wave	1C,2D,4W	11.5	12.5						9.9					20.1
Third Wave	1C,1D,12W	14.7	12.2	10.8		6.7			6.1		10.7	9.8	7.1	
Fourth Wave	ROUTINE	8.5						8.1						12.9
PM WESTERN WB, LA10	QD													
First Wave	1C,1D,4W	38.9	24.8			35.8	24.6	24.8	31.3					38.0
Second Wave	2C,2D,4W	30.7	25.6						26.5	28.7			23.3	23.7
Third Wave	1C,2D,4W	25.2	25.3							26.1				29.8
Fourth Wave	2C,2D,1W	27.1	23.2			16.7	21.5	19.2	15.3			18.3		
PM LOS FELIZ, LA5	QD													
First Wave	2C,2D,12W	11.3	9.1	3.2		6.0		7.5			9.3	9.6		9.6
Second Wave	ROUTINE													
Third Wave	1C,2D,4W	9.5	8.1			6.7			8.6		6.8		8.1	5.2
Fourth Wave	2C,2D,4W	7.2	5.3			5.1	6.2	6.4		6.0			8.0	
PM PASADENA, LA5	V													
First Wave	1C,1D,12W	10.4	7.9	4.4		8.5		8.8		10.2		7.9		10.5
Second Wave	ROUTINE													
Third Wave	ROUTINE						8.6		8.0		8.2		9.4	
Fourth Wave	ROUTINE									6.7				7.9
First Wave														
Second Wave														
Third Wave														
Fourth Wave														

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CHP AREA: WEST LOS ANGELES

AM/PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT			POST — ENFORCEMENT								
			Month 1	Month 2	Month 3	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
AM IMPERIAL WB, LA405	NV													
First Wave	IC, 2D, 4W					6.3	9.2							8.9
Second Wave	ROUTINE					7.4				11.2			9.8	9.1
Third Wave	ROUTINE													6.4
Fourth Wave	ROUTINE								6.3				7.4	
AM CENTURY EB, LA405	NV													
First Wave	ROUTINE					11.4		6.1			9.0			9.6
Second Wave	ROUTINE													8.8
Third Wave	ROUTINE												7.4	
Fourth Wave	ROUTINE								11.6				13.2	
AM CENTURY WB, LA405	NV													
First Wave	ROUTINE						17.1	16.0			18.3			18.8
Second Wave	ROUTINE									13.1			17.1	15.0
Third Wave	ROUTINE													
Fourth Wave	ROUTINE					17.1			20.6				16.5	
PM CENTURY SB, LA405	QD													
First Wave	IC, ID, 12W		7.7	9.5	9.6		10.0		11.3		16.5		11.0	
Second Wave	ROUTINE								9.0		8.5	11.0		
Third Wave	IC, ID, 4W	9.8	10.4			7.3	7.4				12.3			7.9
Fourth Wave	IC, ID, 4W	10.4	12.7			7.8		7.2	5.7	8.0			5.6	
PM MANCHESTER, LA405	QD													
First Wave	ROUTINE						15.7		20.0		19.6			20.3
Second Wave	ROUTINE										17.0	14.8		
Third Wave	ROUTINE									15.4				19.9
Fourth Wave	ROUTINE								15.4				19.4	15.9

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CHP AREA: WEST LÒS ANGELES

AM/PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT			POST — ENFORCEMENT								
			Month 1	Month 2	Month 3	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
AM NATIONAL, LA10	NV													
First Wave	1C,½D,4W	15.9				11.4	13.3	8.8	8.5				11.4	
Second Wave	ROUTINE		12.3				11.3			11.5				11.0
Third Wave	2C,2D,4W	11.2	11.3			8.4	11.8			7.7	10.1			7.9
Fourth Wave	1C,2D,4W	9.5	6.5			6.7	6.5	5.9	7.0		8.3			
AM BUNDY, LA10	NV													
First Wave	2C,1D,4W	15.1				10.5	7.6	9.2	9.7				9.8	
Second Wave	2C,2D,4W	9.8	2.6				7.5				7.8		8.6	8.6
Third Wave	2C,2D,1W	8.6	7.8					7.5	8.8		5.9		6.5	6.0
Fourth Wave	2C,1D,4W	6.8	5.4			5.6	6.7	7.0	5.3		5.5			7.8
AM WILSHIRE, LA405	V													
First Wave	1C,2D,4W	19.6				10.5	12.1	12.0	10.1					11.6
Second Wave	1C,1D,12W	10.9	8.6	8.2		11.2	10.8			10.1				
Third Wave	2C,2D,1W	10.7	9.7			8.4	7.2	10.0		8.0		9.2		
Fourth Wave	2C,1D,4W	8.6	4.1			8.9	8.3	8.5	5.6					
AM MANNING, LA10	QD													
First Wave	1C,1D,12W	9.3	6.1	5.3	6.7			7.0		5.2			7.4	3.9
Second Wave	ROUTINE													
Third Wave	1C,2D,4W	5.9	2.2				6.9		5.7		7.9		7.0	5.7
Fourth Wave	1C,2D,4W	6.7	3.1			3.8	5.1	4.4	6.8		4.0			
AM OLYMPIC/PICO, LA405	QD													
First Wave	2C,2D,4W	14.0				7.7	5.4	9.9	10.1				6.5	
Second Wave	1C,1D,4W	8.3	11.6				10.2					7.5		9.4
Third Wave	2C,1D,4W	9.1	4.9				2.1			7.0	6.5			8.5 11.5
Fourth Wave	2C,2D,1W	9.9	5.9			6.4	3.1	7.2	7.1			6.5		

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CHP AREA: WEST LOS ANGELES

AM/PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT			POST — ENFORCEMENT								
			Month 1	Month 2	Month 3	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
PM MORAGA, LA405	QD													
First Wave	IC, ID, 4W	14.9				13.8	15.2	13.4	16.5					
Second Wave	IC, ID, 4W	14.8	16.4				18.5				12.9			13.5
Third Wave	IC, 4D, 4W	15.0	12.5							12.1	13.8		11.1	6.1
Fourth Wave	IC, ID, 4W	10.9	13.3			7.6	6.3	12.2	8.7	10.5			7.0	
First Wave														
Second Wave														
Third Wave														
Fourth Wave														
First Wave														
Second Wave														
Third Wave														
Fourth Wave														
First Wave														
Second Wave														
Third Wave														
Fourth Wave														
First Wave														
Second Wave														
Third Wave														
Fourth Wave														

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W = Weeks of Enforcement

CHP AREA: SOUTH LOS ANGELES

AM/PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT			POST — ENFORCEMENT								
			Month 1	Month 2	Month 3	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
AM IMPERIAL EB, LA405	QD													
First Wave	1C,½D,4W					5.3	7.1							
Second Wave	1C,1D,4W	6.1	5.0							8.8		5.4		2.2
Third Wave	1C,1D,4W	5.6				1.2	3.1	7.0				5.2		7.1
Fourth Wave	2C,2D,1W	6.5	1.7			8.2	4.6	5.2	6.5		5.0			
AM EL SEGUNDO, LA405	NV													
First Wave	1C,2D,12W		4.4	6.3	5.2		4.8		4.0		5.1			3.5
Second Wave	ROUTINE	4.4				5.2								
Third Wave	2C,2D,1W	4.3	5.8			4.4	5.7			9.1				6.5
Fourth Wave	1C,4D,4W	6.4	6.0			3.2	5.7	5.4	7.0		6.1		4.9	
PM INGLEWOOD SB, LA405	NV													
First Wave	1C,2D,4W		2.2			4.0			3.0	2.8				
Second Wave	1C,1D,4W	2.9	4.0				2.8					3.6		2.3 3.0
Third Wave	2C,1D,4W	3.0	2.8			2.9	3.3				4.3		2.2	1.8
Fourth Wave	ROUTINE	2.9								6.8				3.7 3.6
PM ARTESIA, LA405	NV													
First Wave	2C,1D,4W					11.3	11.9	8.3						
Second Wave	1C,1D,4W	9.8				9.3			14.5		10.6			
Third Wave	2C,2D,4W	11.4	7.5			9.2	12.2				9.2		6.6	8.6
Fourth Wave	2C,2D,4W	9.1				5.9		6.8	8.3		8.7		12.0	
PM NORMANDIE, LA405	V													
First Wave	1C,1D,4W					5.0	8.9		4.7		5.0			
Second Wave	1C,2D,4W	4.9	4.4				5.1			5.1				
Third Wave	ROUTINE	5.1												5.4
Fourth Wave	1C,1D,4W	5.4	3.9			3.4		8.0	9.1		7.4			5.8

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CHP AREA: SOUTH LOS ANGELES

AM/PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT			POST — ENFORCEMENT								
			Month 1	Month 2	Month 3	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
PM HAWTHORNE, LA405	QD													
First Wave	ROUTINE	6.3						7.6	8.5				5.0	
Second Wave	ROUTINE													
Third Wave	ROUTINE					8.8	6.6							
Fourth Wave	ROUTINE									7.1		5.2		6.1
First Wave														
Second Wave														
Third Wave														
Fourth Wave														
First Wave														
Second Wave														
Third Wave														
Fourth Wave														
First Wave														
Second Wave														
Third Wave														
Fourth Wave														
First Wave														
Second Wave														
Third Wave														
Fourth Wave														

KEY: Officer Visibility
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ENFORCEMENT
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D = Day per week
W = Weeks of Enforcement

CHP AREA: WEST VALLEY

AM/PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT			POST — ENFORCEMENT								
			Month 1	Month 2	Month 3	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
AM COLDWATER CYN, LA101	QD													
First Wave	1C,1D,4W	7.1				5.5	4.9	4.5	5.1					6.0
Second Wave	ROUTINE													5.0
Third Wave	1C,2D,4W	5.5	5.3			4.0			4.1	5.1			3.6	
Fourth Wave	2C,2D,1W	4.3	4.0			3.5	2.2	2.5	4.3			4.1		
AM WOODMAN, LA101	NV													
First Wave	1C,2D,4W	8.8				4.8	4.6	4.4	4.8					6.9
Second Wave	1C,½D,4W	5.9	5.1				3.5					3.6		5.3
Third Wave	2C,2D,1W	5.3	3.8			3.6	5.1	4.9		4.4			4.2	
Fourth Wave	1C,1D,4W	4.7	3.3			3.5	4.6	4.5	3.5		3.7		5.0	
AM BURBANK, LA170	QD													
First Wave	1C,4D,4W	10.3				5.7	8.6	5.7	5.5					7.4
Second Wave	1C,2D,4W	6.8	8.1				8.1					4.7		5.7 7.0
Third Wave	2C,1D,4W	6.4	3.0			3.9		3.6		5.3			5.8	
Fourth Wave	2C,2D,1W	5.5				3.8	4.0	7.2	5.7			2.2		
AM LAUREL CYN, LA101	QD													
First Wave	ROUTINE	7.3												6.3
Second Wave	ROUTINE													
Third Wave	ROUTINE													
Fourth Wave	ROUTINE													
First Wave														
Second Wave														
Third Wave														
Fourth Wave														

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W = Weeks of Enforcement

CHP AREA: EL CAJON

AM/PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT			POST — ENFORCEMENT								
			Month 1	Month 2	Month 3	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
AM EL CAJON BLVD, SD8														
First Wave														
Second Wave														
Third Wave	1C,½D,12W		0.9	1.3	1.5									
Fourth Wave	1C,4D,4W	2.3	1.5							1.2	1.2			
AM SD94 - SD94	QD													
First Wave	1C,2D,4W	0.6						1.5	0.6	0.5				
Second Wave	1C,1D,4W	0.6	0.5			0.8	0.7	1.5	1.2	0.9	0.5			
Third Wave	ROUTINE													
Fourth Wave	1C,1D,4W	1.0	0.4							1.5	1.0			
AM COLLEGE GROVE	NV													
First Wave	1C,½D,8W	5.7												
Second Wave	ROUTINE													
Third Wave	ROUTINE													
Fourth Wave	ROUTINE	4.8	3.9											
First Wave														
Second Wave														
Third Wave														
Fourth Wave														
First Wave														
Second Wave														
Third Wave														
Fourth Wave														

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ENFORCEMENT
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D = Day per week
W = Weeks of Enforcement

CHP AREA: SAN DIEGO

AM/PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT			POST — ENFORCEMENT								
			Month 1	Month 2	Month 3	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
AM SD805 - SD94	V													
First Wave	1C,2D,4W	5.6				3.3	3.6	3.2	3.0	2.9		3.1		
Second Wave	1C,½D,4W	3.0	4.8			4.0	5.2		3.3			4.1	4.0	3.1
Third Wave	2C,1D,4W	4.1	6.2			3.0	2.9	2.2	1.9	2.7	1.1			
Fourth Wave	2C,2D,1W	2.3									4.5	4.1	3.7	4.0 4.8
AM SD15 - SD94	V													
First Wave	1C,1D,12W	6.1	6.2	3.4	4.1	3.0	4.7							
Second Wave	1C,1D,4W	4.7	2.2			2.7	3.2		5.0			5.4		4.9 3.5
Third Wave	2C,2D,1W	4.4	3.0			2.6	2.2	1.6	3.7	2.0	3.4			
Fourth Wave	1C,1D,4W	2.9									4.2	3.3	2.6	4.0
AM WARING, SD8														
First Wave														
Second Wave														
Third Wave	1C, 1D, 1W							2.1			2.8			2.1 1.9 2.7
Fourth Wave	1C, 2D, 4W	2.3									2.2	2.2	2.1	2.5
PM TEXAS, SD8														
First Wave														
Second Wave														
Third Wave														
Fourth Wave	1C,2D,4W		1.5			3.1	2.9		2.8					
First Wave														
Second Wave														
Third Wave														
Fourth Wave														

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D = Day per week
W = Weeks of Enforcement

CHP AREA: WESTMINSTER

AM/PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT			POST — ENFORCEMENT								
			Month 1	Month 2	Month 3	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
AM KATELLA, OR605	NV													
First Wave	1C,1D,4W	3.9	4.8			2.8	4.0	1.6	3.1	1.6				
Second Wave	1C,½D,4W	2.6	4.1				3.4	3.9			2.9		1.7	2.6
Third Wave	ROUTINE													
Fourth Wave	ROUTINE									3.9				3.7
PM LAKEWOOD SB, LA405	NV													
First Wave	1C,2D,4W	13.1	10.3			4.2	6.2	13.1					6.0	
Second Wave	1C,½D,12W	10.0	4.2	3.5	5.0			1.6				4.6		6.1
Third Wave	2C,½D,4W	6.1				3.7	5.9			3.2		1.5		5.9
Fourth Wave	1C,1D,4W	4.3	2.0			1.9	2.6	5.9	2.6		3.4			6.9
PM SPRING, LA405	V													
First Wave	1C,2D,4W	11.0	6.3				7.0	6.4	4.2					
Second Wave	1C,½D,12W	5.3	4.6	4.8	4.5			7.2				3.9		5.2
Third Wave	2C,2D,1W	5.6	3.5			4.9	2.9			1.1				0.8 5.5
Fourth Wave	ROUTINE									8.4				
PM CARSON, OR605	V													
First Wave	ROUTINE	14.1												
Second Wave	1C,1D,4W	11.2	8.3				10.4	10.3			9.6		7.7	7.2
Third Wave	1C,½D,4W	9.4				4.5	5.1			11.6			7.3	8.4
Fourth Wave	1C,1D,12W	9.1	10.3	9.1	8.8	11.0	7.5		6.5	7.6	9.4			
PM EUCLID, OR405														
First Wave	ROUTINE													
Second Wave	ROUTINE													
Third Wave	ROUTINE									5.9	3.9	5.4	7.6	
Fourth Wave	1C,2D,4W	7.6	2.9			5.9	4.3	3.9			5.7			

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ENFORCEMENT
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D = Day per week
W = Weeks of Enforcement

CHP AREA: SANTA ANA

AM / PM RAMP	Enforcement Level	Mean Pre-Enforcement Level	ENFORCEMENT			POST — ENFORCEMENT								
			Month 1	Month 2	Month 3	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 or later
AM ORANGETHORPE WB, OR91 QD														
First Wave	1C,2D,4W	7.6	5.9			5.7	4.6	4.3	6.1				6.7	
Second Wave	1C,1D,4W	6.4	6.6			3.7			5.4			3.7		3.3 3.1
Third Wave	1C,1D,4W	3.9				4.3	6.3					6.2		2.6 4.9
Fourth Wave	2C,2D,1W	4.9	3.5			7.3	5.4	6.4	4.1		4.9			4.3 3.0
PM ORANGETHORPE EB, OR91 NV														
First Wave	1C,2D,4W	9.2	5.4			4.7	5.0	6.5				6.6	4.8	
Second Wave	1C,1D,4W	5.7	5.1			5.2				7.3				5.4 6.0
Third Wave	2C,2D,1W	6.0	6.6			2.8	3.6		5.1					6.0 4.2
Fourth Wave	2C,1D,4W	4.3	4.1			4.1	4.2	4.0	5.0		5.0			4.5
First Wave														
Second Wave														
Third Wave														
Fourth Wave														
First Wave														
Second Wave														
Third Wave														
Fourth Wave														
First Wave														
Second Wave														
Third Wave														
Fourth Wave														

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APPENDIX F

RAMP DELAYS
BEFORE
AND
AFTER
ENFORCEMENT

L.A. RAMPS DELAY PER VEHICLE
BY LOCATION AND ENFORCEMENT PHASE
WEIGHTED BY METERED LANE TRAFFIC VOLUME

mean(standard deviaion)[sample size]

LOCATION	IDENT	BEFORE	AFTER	IS CHANGE STATISTICALLY SIGNIFICANT?	DIRECTION?
I10/CRENSHAW	ACRN	38.8(41.2)[105]	71.3(63.5)[179]	**yes**	**up**
I10/MANNING	AMNG	150.4(142.3)[71]	147.0(151.8)[143]	no	--
I10/NATIONAL	ANAT	145.3(110.6)[70]	123.0(98.6)[179]	no	--
I10/VENICE	AVEN	116.9(96.6)[69]	152.7(110.2)[108]	yes	up
I10:E/WESTERN	AWSTE	22.0(17.7)[70]	29.8(17.8)[216]	yes	up
I10:W/WESTERN	AWSTW	14.3(8.3)[71]	30.2(16.9)[180]	yes	up
SR11/FLORENCE	BFLR	140.0(76.4)[104]	177.2(84.9)[214]	yes	up
SR11/MANCHESTR:E	BMANE	102.5(66.5)[72]	100.5(62.4)[72]	no	--
SR11/VERNON	BVER	122.3(79.6)[67]	99.1(63.8)[216]	yes	down
SR91/LAKEWOOD:N	DLAKN	12.3(10.1)[106]	27.1(13.3)[178]	yes	up
SR91/ORANGTHRP:E	DORTE	20.9(11.4)[47]	22.7(9.7)[142]	no	--
SR91/ORANGTHRP:W	DORTW	34.7(18.1)[68]	38.5(11.7)[214]	no	--
US101/COLDWATER	ECLD	79.8(53.8)[71]	55.1(47.4)[179]	yes	down
US101/WOODMAN	EWOD	58.5(33.0)[102]	44.9(23.8)[143]	yes	down
SR170/BURBANK	FBUR	15.3(8.8)[89]	17.7(8.9)[120]	no	--
I405/LAKEWOOD:S	GLAKS	145.4(123.0)[78]	163.0(113.1)[190]	no	--
I405/MORAGA	GMOR	40.6(23.1)[84]	45.6(28.9)[168]	no	--
I405/OLYMPC&PICO	GOLY	18.9(10.8)[119]	37.7(22.2)[193]	yes	up
I405/SPRING	GSPR	44.3(49.0)[74]	85.6(76.6)[156]	yes	up
I405/WISHIRE	GWIL	14.6(11.5)[60]	35.2(12.3)[148]	yes	up
I605/BEVERLY	HBEV	4.9(4.6)[48]	12.2(6.4)[72]	yes	up
I605/FIRESTONE	HFIR	10.9(6.1)[48]	24.8(17.4)[95]	yes	up
I605/IMPERIAL	HIMP	59.8(50.6)[60]	77.9(45.5)[118]	yes	up
I605/KATELLA	HKAT	13.2(13.1)[48]	36.8(28.8)[142]	yes	up
I605/SOUTH ST.	HSOU	6.6(2.9)[48]	11.9(6.9)[70]	yes	up
I605/WHITTIER:E	HWHTE	3.7(2.0)[48]	18.4(9.5)[141]	yes	up
I605/WHITTIER:W	HWHTW	5.7(2.9)[48]	16.7(4.8)[94]	yes	up
I5/BURBANK	5BUR	8.1(3.8)[54]	13.6(3.3)[27]	yes	up
I5/COLORADO	5COL	11.7(11.0)[45]	31.7(28.3)[71]	yes	up
I5/HOLLYWOOD	5HOL	26.2(13.0)[48]	27.6(12.1)[24]	no	--
I5/LOS FELIZ	5LFE	39.8(22.3)[66]	20.4(12.2)[109]	yes	down
I5/PASADENA	5PAS	26.6(16.2)[42]	28.7(12.3)[67]	no	--
I5/TUXFORD	5TUX	8.6(4.0)[54]	12.2(4.9)[54]	yes	up

APPENDIX G

SAMPLE SURVEY FORMS

PRE-ENFORCEMENT SURVEY

VENTURA FREEWAY
CORRIDOR DRIVER SURVEY

Dear Motorist:

The California Department of Transportation is evaluating the effectiveness of freeway ramp control projects, special bus and carpool lanes, and other transportation projects in the Los Angeles Metropolitan Area.

If you or anyone in your household uses the Ventura Freeway, it would be appreciated if the driver would answer the questions below. This would greatly aid the planning and evaluation of future transportation projects in the Los Angeles Area as well as elsewhere in California. All information is anonymous and will be kept confidential. Thank you for your cooperation.

FIRST, SOME QUESTIONS ABOUT YOUR TRAVEL ON THE VENTURA FREEWAY?

1. What is the main purpose of your trips using the Ventura Freeway?

( ) Work (regular commuting)　( ) Business (work related)　( ) Social, recreational
( ) School　( ) Shopping　( ) Other ____________________

2. How often are these trips made?

( ) Once a month or less　( ) 2 or 3 times a week
( ) 2-5 times a month　( ) 4 or 5 times a week

3. What time do you usually start your trip in the morning? ____________ a.m.　In the afternoon? ____________ p.m.

4. Where do you usually enter the Ventura Freeway in the morning?
( ) ____________________ (street nearest freeway on-ramp)
( ) ____________________ (other freeway)

Where do you usually enter the Ventura Freeway in the afternoon?
( ) ____________________ (street nearest freeway on-ramp)
( ) ____________________ (other freeway)

5. How long does your complete trip usually take in the morning? _____ minutes.　Your return trip in the afternoon? ______ min.

6. How long is your total one-way trip? _______ miles.

7. How do you usually make the trip?

( ) Drive alone　( ) Carpool with ________ (no.) people (include driver)
( ) Bus　( ) Other ____________________

NEXT, SOME QUESTIONS ABOUT THE SIGNAL LIGHTS USED TO CONTROL TRAFFIC ON THE VENTURA FREEWAY ON-RAMPS?

1. How long do you usually wait in line at these signals before entering the freeway?

____________ minutes in the morning;　_________ minutes in the evening.

2. Did you use the Ventura Freeway regularly before the ramp signals were installed?

( ) Yes　( ) No

If Yes, how has your total travel time changed since the meters were installed?

Morning trip time has ( ) Increased by ________ minutes; ( ) Decreased by _________ minutes; ( ) Not changed.

Evening trip time has ( ) Increased by ________ minutes; ( ) Decreased by _________ minutes; ( ) Not changed.

3. How strongly do you agree with the following statements regarding the ramp signal lights?

The ramp signal lights:	Agree Strongly	Agree Slightly	Neither Agree Nor Disagree	Disagree Slightly	Disagree Strongly
Make it easier to merge onto the freeway	( )	( )	( )	( )	( )
Contribute to better freeway flow	( )	( )	( )	( )	( )
Increase accidents on the ramps themselves	( )	( )	( )	( )	( )
Increase freeway accidents	( )	( )	( )	( )	( )
Reduce gasoline consumption	( )	( )	( )	( )	( )
Reduce air pollution	( )	( )	( )	( )	( )
Shorten overall trip times	( )	( )	( )	( )	( )
Cause congestion on nearby city streets	( )	( )	( )	( )	( )

NEXT, SOME QUESTIONS ABOUT THE SPECIAL BYPASS LANES FOR BUSES AND CARPOOLS ON SOME VENTURA FREEWAY ON-RAMPS.

1. Bypass lanes for buses and carpools with two or more persons have been installed on some Ventura Freeway on-ramps. Did these ramps cause you to:

   ☐ Change route to use bypass ramp
   ☐ Change route to avoid bypass ramp
   ☐ Join or form a carpool
   ☐ Increase size of carpool
   ☐ Other ____________________

   ☐ No, I made no changes as a result of the special lanes.

2. Have you ever used the bus/carpool lanes? ☐ Yes ☐ No

   If yes, how often do you use the lanes?
   ☐ Once a month or less ☐ 2 or 3 times a week
   ☐ 2-5 times a month ☐ 4 or 5 times a week

   and how much time do you usually save by using the bypass lanes?

   ________ minutes in the morning; ________ minutes in the evening.

3. Have you ever seen the Highway Patrol stopping a driver for using the bus/carpool lane without the proper number of occupants? ☐ Yes ☐ No

4. Have you ever received a ticket or verbal warning from the Highway Patrol for using the bus/carpool lane illegally? ☐ Yes ☐ No

   If Yes, ______ (number of tickets) ______ (number of warnings)

5. What percentage of the drivers in the bus/carpool lane would you estimate use the lane illegally? ______ %

6. Do you think that drivers using the bus/carpool lane illegally are ticketed by the Highway Patrol

   ☐ Always ☐ Frequently ☐ Sometimes ☐ Infrequently ☐ Never?

7. Do you feel that the use of the bus/carpool lane by non-carpoolers is a

   ☐ Serious problem ☐ Minor problem ☐ No problem ☐ Other ____________________

8. How strongly do you agree or disagree with the following statements regarding the bus/carpool lanes?

The bus/carpool lanes:	Agree Strongly	Agree Slightly	Neither Agree Nor Disagree	Disagree Slightly	Disagree Strongly
Save time for carpoolers	☐	☐	☐	☐	☐
Contribute to better freeway flow	☐	☐	☐	☐	☐
Increase accident potential	☐	☐	☐	☐	☐
Motivate people to join carpools	☐	☐	☐	☐	☐
Reduce gasoline consumption	☐	☐	☐	☐	☐
Reduce air pollution	☐	☐	☐	☐	☐
Are unfair to non-carpooling drivers	☐	☐	☐	☐	☐
Cause congestion on nearby city streets	☐	☐	☐	☐	☐

FINALLY, SOME QUESTIONS ABOUT YOU AND YOUR VIEWS REGARDING FUTURE TRANSPORTATION NEEDS.

1. How many cars are there in your household? ________ (No.) Licensed drivers? ________ (No.)
2. What type of car do you usually drive on the Ventura Freeway? ( ) Standard ( ) Compact ( ) Subcompact
   ( ) Luxury ( ) Van ( ) Sports Car ( ) Station Wagon ( ) Other ____________________
3. Sex: ( ) Female ( ) Male
4. Age Group: ( ) Under 20 ( ) 20-29 ( ) 30-44 ( ) 45-64 ( ) 65 and over
5. What is the combined yearly income of your household? ( ) Under $5,000 ( ) $5,000 to $9,999 ( ) $10,000 to $14,999
   ( ) $15,000 to $19,999 ( ) $20,000 to $29,999 ( ) $30,000 and over
6. How do you feel about the following statements regarding California's future transportation needs?

	Agree Strongly	Agree Slightly	Neither Agree Nor Disagree	Disagree Slightly	Disagree Strongly
More freeways should be built	( )	( )	( )	( )	( )
More bus service is needed	( )	( )	( )	( )	( )
More special freeway lanes are needed for buses	( )	( )	( )	( )	( )
More special freeway lanes are needed for carpools	( )	( )	( )	( )	( )
Autos should be made more fuel-efficient	( )	( )	( )	( )	( )
Autos should be made less polluting	( )	( )	( )	( )	( )
Stoplights should be placed on more entry ramps to control traffic flow on freeways	( )	( )	( )	( )	( )
Buses should be allowed to bypass stoplights on freeway entry ramps	( )	( )	( )	( )	( )
Carpools should be allowed to bypass stoplights on freeway entry ramps	( )	( )	( )	( )	( )
The Highway Patrol should enforce special bus and carpool lanes more often	( )	( )	( )	( )	( )
More enforcement of 55 MPH speed limit is needed	( )	( )	( )	( )	( )
More rail rapid transit should be planned	( )	( )	( )	( )	( )
Buses should be given special treatment at bridge toll plazas	( )	( )	( )	( )	( )
Carpools should be given special treatment at bridge toll plazas	( )	( )	( )	( )	( )
Work hours should be staggered to relieve peak period congestion	( )	( )	( )	( )	( )

WE WOULD APPRECIATE YOUR ADDITIONAL COMMENTS: ____

____

____

____

____

THANK YOU FOR YOUR COOPERATION.
PLEASE FOLD TWICE, STAPLE, AND MAIL (NO STAMP REQUIRED)

Date ________ (month), ________ (day), 19 ________

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LOS ANGELES, CALIFORNIA 90051

POST-ENFORCEMENT SURVEY

FIRST, SOME QUESTIONS ABOUT YOUR TRAVEL ON THE SANTA MONICA FREEWAY (Interstate Route 10):

1. How often do you use the Santa Monica Freeway?
☐ Once a *month* or less ☐ 2-5 times a *month* ☐ 2 or 3 times a *week* ☐ 4 times a *week* or more

2. How do you usually use the Freeway?
☐ Drive alone ☐ Bus ☐ Carpool with______(no.) people (include driver)
☐ Other____________________

3. Did you use the Santa Monica Freeway regularly before signal lights were installed to control traffic on the freeway ramps? . . . . ☐ Yes ☐ No

If YES, how has your *total* travel time changed since the lights were installed?

Morning trip time has ☐ Increased by______minutes; ☐ Decreased by______minutes; ☐ Not changed

Evening trip time has ☐ Increased by______minutes; ☐ Decreased by______minutes; ☐ Not changed

NEXT, SOME QUESTIONS ABOUT THE SPECIAL BYPASS LANES FOR BUSES AND CARPOOLS ON SOME SANTA MONICA FREEWAY ON-RAMPS:

1. Bypass lanes for buses and carpools with two or more persons have been installed on some Santa Monica Freeway on-ramps. Have you ever used these lanes? . . . . . . ☐ Yes ☐ No

2. Have you ever seen the Highway Patrol stopping a driver for using the bus/carpool lane without the proper number of occupants? . . . . ☐ Yes ☐ No

3. Have you ever received a ticket or verbal warning from the Highway Patrol for using the bus/carpool lane illegally? . . . . ☐ Yes ☐ No

4. What percentage of the drivers in the bus/carpool lane would you estimate use the lane illegally?______%

5. Do you think that drivers using the bus/carpool lane illegally are ticketed by the Highway Patrol?
☐ Always ☐ Frequently ☐ Sometimes ☐ Infrequently ☐ Never

6. Do you feel that the use of the bus/carpool lane by non-carpoolers is a
☐ Serious problem ☐ Minor problem ☐ No problem
☐ Other____________________

7. During the past year, do you feel that Highway Patrol enforcement of special bus and carpool lanes has
☐ Increased ☐ Decreased ☐ Stayed about the same?

WE WOULD APPRECIATE YOUR ADDITIONAL COMMENTS:

____

____

____

____

THANK YOU FOR YOUR COOPERATION.

PLEASE FOLD, STAPLE, AND MAIL (No Postage Required) Date______________19____
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DEPARTMENT OF TRANSPORTATION
TRAFFIC OPERATION BRANCH

DISTRICT 7

BOX 2304, TERMINAL ANNEX

LOS ANGELES, CALIFORNIA 90051

SANTA MONICA FREEWAY
CORRIDOR DRIVER SURVEY

Dear Motorist:

The California Department of Transportation is evaluating the effectiveness of freeway ramp control projects, special bus and carpool lanes, and other transportation projects in the Los Angeles Metropolitan Area.

If you or anyone in your household uses the Santa Monica Freeway, it would be appreciated if the driver would answer the questions on the reverse side. This would greatly aid the planning and evaluation of future transportation projects in the Los Angeles Area as well as elsewhere in California. All information is anonymous and will be kept confidential.

Thank you for your cooperation.

APPENDIX H

SURVEY RESPONSE RATES
OF
INDIVIDUAL PROJECTS

- Pre-enforcement Surveys
- Post-enforcement Surveys

Appendix H

SURVEY RESPONSE RATES FOR INDIVIDUAL PROJECTS

PRE-ENFORCEMENT SURVEY
(1980)

	SURVEY CATEGORY			
PROJECT TYPE	VIOLATORS	CARPOOLERS	GENERAL TRAFFIC	TOTAL
Los Angeles Ramps				
National, LA10				
Surveys Delivered	231	162	654	1047
Returned	55	44	199	298
% Returned	23.8%	27.2%	30.4%	28.5%
Woodman, LA101				
Surveys Delivered	206	250	542	998
Returned	55	58	185	298
% Returned	26.7%	23.2%	34.1%	30.0%
Vernon, LA11				
Surveys Delivered	273	257	289	819
Returned	30	23	47	100
% Returned	11.0%	9.0%	16.3%	12.2%
Olympic/Pico, LA405				
Surveys Delivered	612	280	1241	2133
Returned	160	73	370	603
% Returned	26.1%	26.1%	29.8%	28.3%
Colorado, LA5				
Surveys Delivered	52	313	279	644
Returned	13	56	72	141
% Returned	25.0%	17.9%	25.8%	21.9%
Orangethorpe, OR91				
Surveys Delivered	127	200	498	825
Returned	26	42	119	187
% Returned	20.5%	21.0%	23.9%	22.7%

San Diego Ramps				
I-15 & I-805, SD94				
Surveys Delivered	178	815	2341	3334
Returned	14	140	398	552
% Returned	7.9%	17.2%	17.0%	16.6%
El Cajon, SD8				
Surveys Delivered				
Returned				
% Returned				
San Jose Ramp				
Guadalupe, SC101				
Surveys Delivered	360	200	770	1320
Returned	36	53	220	309
% Returned	10.0%	26.5%	28.9%	23.4%
Mainline HOV Lanes				
Marin 101				
Surveys Delivered	268	392	454	1114
Returned	26	117	96	239
% Returned	9.7%	29.9%	21.2%	21.5%
Alameda 580				
Surveys Delivered	222	564	431	1217
Returned	54	95	158	307
% Returned	24.3%	16.8%	36.6%	25.2%
San Bernardino Freeway				
Surveys Delivered	193	349	564	1106
Returned	14	90	121	225
% Returned	7.3%	25.8%	21.5%	20.3%
SF/Oakland Bay Bridge				
Surveys Delivered	254	499	960	1713
Returned	38	171	264	473
% Returned	15.0%	34.3%	27.5%	27.6%

POST-ENFORCEMENT SURVEY
(1981)

Los Angeles Ramps				
National, LA10				
Surveys Delivered	169	426	752	1347
Returned	41	126	257	424
% Returned	24.3%	29.6%	34.2%	31.5%
Woodman, LA101				
Surveys Delivered	157	476	1111	1744
Returned	25	144	422	591
% Returned	15.9%	30.3%	38.0%	33.9%

Vernon, LA11				
Surveys Delivered	187	623	405	1215
Returned	12	74	68	154
% Returned	6.4%	11.9%	16.8%	12.7%
Olympic/Pico, LA405				
Surveys Delivered	338	861	1415	2614
Returned	91	264	441	796
% Returned	26.9%	30.7%	31.2%	30.5%
Colorado, LA5				
Surveys Delivered	61	417	759	1237
Returned	17	113	222	352
% Returned	27.9%	27.1%	29.2%	28.5%
Orangethorpe, OR91				
Surveys Delivered	32	341	500	873
Returned	13	97	137	247
% Returned	40.6%	28.4%	27.4%	28.3%
<u>San Diego Ramps</u>				
I-15 & I-805, SD94				
Surveys Delivered	93	1164	2950	4207
Returned	5	198	604	807
% Returned	5.4%	17.0%	20.5%	19.2%
El Cajon, SD8				
Surveys Delivered	30	711	2517	3258
Returned	6	151	553	710
% Returned	20.0%	20.1%	22.0%	21.5%
<u>San Jose Ramp</u>				
Guadalupe, SC101				
Surveys Delivered	252	208	785	1245
Returned	41	110	282	433
% Returned	16.3%	52.9%	35.9%	34.8%
<u>Mainline HOV Lanes</u>				
Marin 101				
Surveys Delivered	77	442	452	971
Returned	24	167	143	334
% Returned	31.2%	37.8%	31.6%	34.4%
Alameda 580				
Surveys Delivered	105	327	482	914
Returned	36	133	227	396
% Returned	34.3%	40.7%	47.1%	43.3%
San Bernardino Freeway				
Surveys Delivered				
Returned				
% Returned				

SF/Oakland Bay Bridge				
Surveys Delivered	92	2400	993	3486
Returned	29	1124	348	1501
% Returned	31.2%	46.8%	35.0%	43.1%

*U.S. GOVERNMENT PRINTING OFFICE : 1982 O-361-428/2072