U.S. Department of Transportation

Use of Videotape in HOV Lane Surveillance and Enforcement

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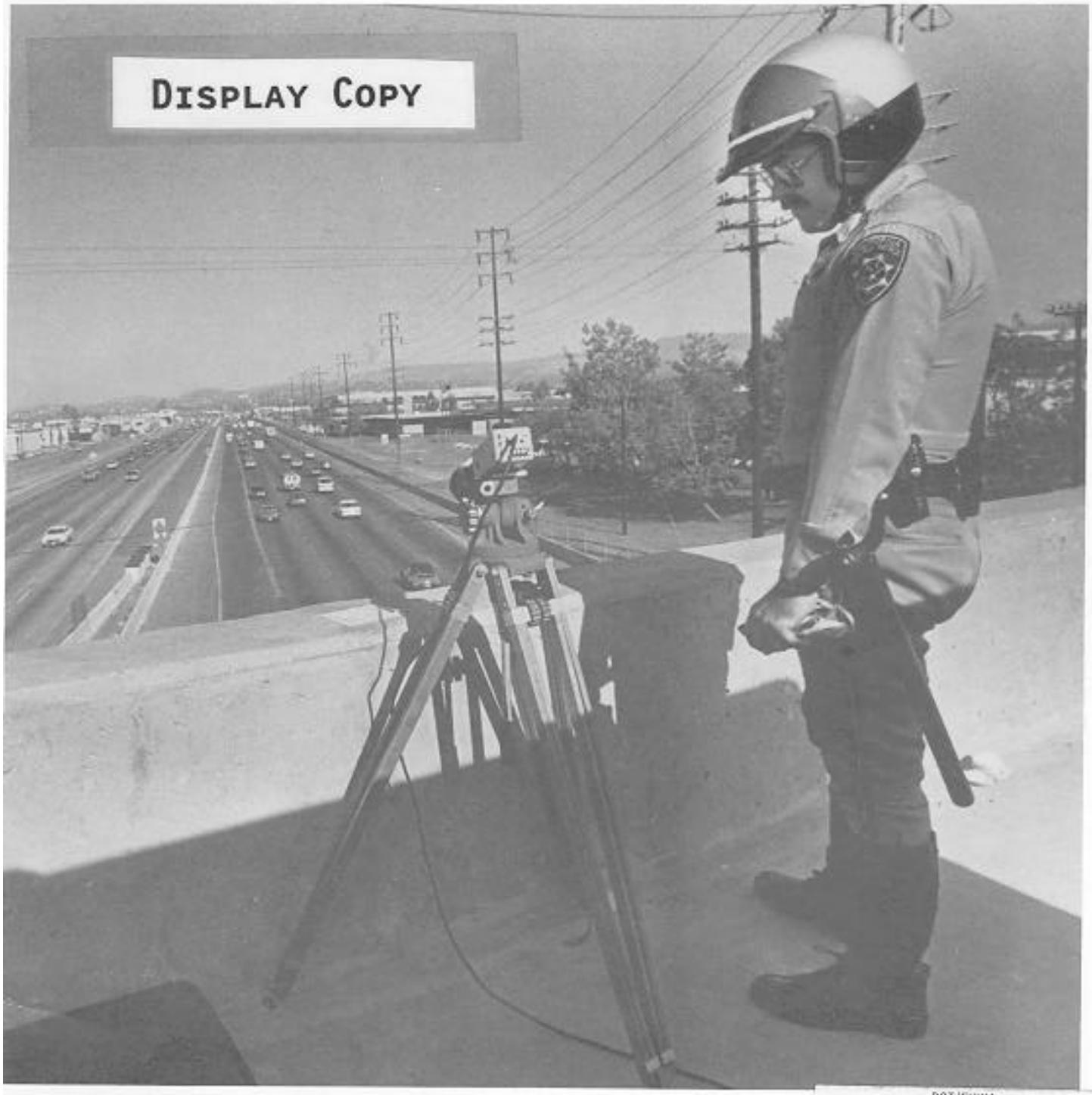

USE OF VIDEOTAPE

IN

HOV LANE

SURVEILLANCE AND ENFORCEMENT

FINAL REPORT

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Submitted to

State of California
Department of Transportation

under Contract 55 G710

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in
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with

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PREFACE AND ACKNOWLEDGEMENTS

This report covers a six-month study designed to explore the use of vidoetape in HOV lane surveillance and enforcement. The study is an extension of an earlier investigation of the effects of different enforcement strategies and engineering designs on violation rates on California's mainline HOV lanes.

The report has been prepared in the Los Altos, California offices of SYSTAN, Inc. under Contract No. 55 G710 with the California Department of Transportation (CALTRANS). The project was jointly sponsored by the California Highway Patrol (CHP). Mr. Philip Jang, Chief of the HOV Systems Branch of CALTRANS Division of Traffic Operations served as project administrator, while Scott McGowen of CALTRANS acted as the project's technical monitor.

A steering committee comprised of representatives from CALTRANS, the CHP and the Federal Highway Administration (FHWA) was responsible for overall project guidance and for approving the products of major project tasks. In addition to Mr. Jang and Mr. McGowen, other members of the steering committee included: Assistant Chief N.K. Newman of the CHP's Border Division; Mr. Robert Anderson and Mr. Bill Shoemaker of CALTRANS District 4 (San Francisco); Mr. Glen Clinton of the FHWA; Mr. Joe El Harake of CALTRANS District 12 (Orange County); Mr. Ron Klusza of CALTRANS District 7 (Los Angeles); and Lieutenants Ron Phulps and Shawn Watts of the CHP's Long Range Planning Section.

SYSTAN's project manager and principal investigator was Dr. John W. Billheimer. Mr. Eric Lin of SYSTAN assisted with data coordination and analysis. Mr. Ken Kaylor of ATD Inc. was responsible for developing, adapting, and coordinating the camera equipment and monitors used in the study, while Mr. Charles Shade of ATD supervised the field installation and operation of the equipment. Ms. Fran Vella of Phrasmaker Word Processing prepared the Final Report.

Representatives of CALTRANS and the CHP who assisted in coordinating the field tests at the heart of the current study included:

Lt. Mike Howard, CHP (Santa Ana)
Mr. Andrew M. Miceli, CALTRANS (District 7)
Sgt. John Steel, CHP (Santa Ana)
Lt. Ed Whitby, CHP (Westminster)

SYSTAN wishes to thank all those who provided information and insights on the enforcement and operation of California's mainline HOV lanes, and acknowledges full responsibility for the analysis, interpretation, and presentation of the data they provided.

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1.1 INTRODUCTION

1.1.1 Background

Enforcement of California's HOV lanes currently requires substantial commitments of California Highway Patrol (CHP) personnel and equipment. Personnel costs for enforcing the state's ten mainline HOV lanes alone will exceed $400,000 in 1990. HOV lane enforcement has other costs as well. These include the risks of high-speed pursuit in lanes adjacent to stop-and-go traffic and the deterioration of traffic flow when tickets are issued during peak commute periods.

It has been suggested that using video equipment to assist in HOV lane enforcement could reduce the requirements for patrol officers, increase citation rates, and minimize freeway disruption. The current investigation has been designed to extend past studies of HOV lane enforcement by testing both the feasibility and accuracy of the use of video equipment in HOV lane surveillance.

1.1.2 Objective

The objective of the current study has been to demonstrate and test the use of video equipment in determining vehicle occupancy, documenting violator identity, and aiding enforcement of HOV lanes.

1.2 APPROACH

Six days of field tests were undertaken to explore the use of videotape in HOV lane surveillance and enforcement. Three days were devoted to testing the effects of different camera positions, filter adjustments, and monitor displays in the absence of enforcement personnel. Once a promising combination of camera positions and displays had been identified, they were tested with enforcement personnel present on specific HOV lanes in Southern California. Two days of HOV lane tests were undertaken on Los Angeles Route 91, with one day on Orange County Route 55. During these tests, personnel from ATD Inc. set up cameras in different

configurations on and under freeway overpasses and established a three-way monitor in a separate video control unit (See Exhibit 1 .1). CHP officers stationed downstream from the video control unit were asked to observe selected video-identified violators to ascertain the actual number of occupants in the vehicle. At the same time, trained CALTRANS observers were stationed on the overpass to provide manual counts of violations. The results of these tests were then analyzed to determine the feasibility, accuracy, and cost-effectiveness of using video cameras in HOV lane surveillance and enforcement.

1.3 EXPERIMENTAL FINDINGS

1.3.1 Equipment

Field tests showed that it is technologically possible to record several accurate views of vehicles traveling in mainline HOV lanes. Specifications and costs of the equipment needed for videotape surveillance are summarized below.

Cameras. Best results are obtained with high speed color cameras capable of achieving exposure times of 1/1000 of a second. A14:1 zoom lens is needed to focus on oncoming vehicles at distances of approximately 1200 feet. Cameras placed at eye-level on the freeway itself should be small and unobtrusive.

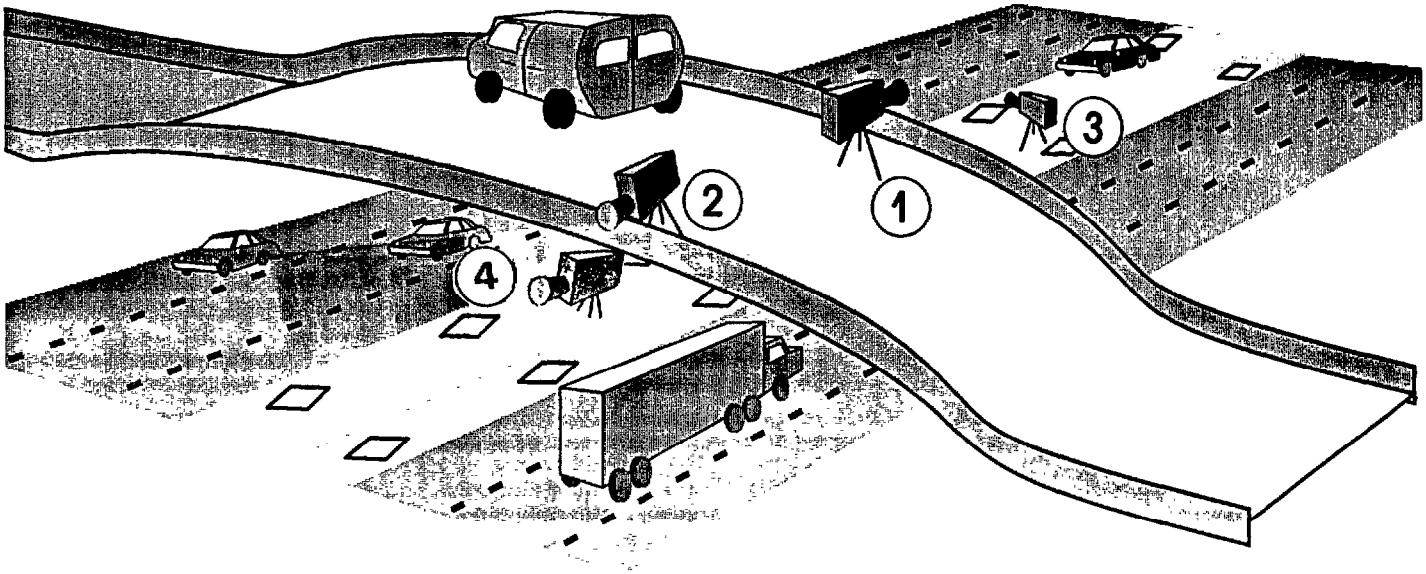
Auxiliary Equipment. Two monitors with split screen capability are required in the control van. One monitor provides an on-line review capability, while the other provides a permanent record of all camera views. A special effects generator should be used to make the exact time and location a permanent part of the videotape record.

Polarizing filters help to solve problems with glare from shiny cars and windshields, although they reduce the light-gathering capability of the cameras. Infra-red cameras and light sources can be used to document license plates after dark by videotaping the rear license plates of departing cars. However, it does not appear feasible to videotape oncoming vehicles under conditions of darkness or low visibility. Results are not clear and the infra-red light source can distract oncoming drivers.

EXHIBIT 1.1

TYPICAL FIELD TEST SET-UP AND MONITOR OUTPUT

1. Oncoming View
2. License View from Bridge
3. Driver's Eye Level View
4. License View from Roadway



Camera Positions. For real-time decision making, viewers seemed to prefer a monitor display showing three views of the suspect vehicles: (1) An oncoming view; (2) A view of the license plate; and (3) An oblique view downward into the passenger seat (camera positions 1, 2, and 3 in Exhibit 1 1). When decisions regarding vehicle occupancy can be delayed for a more leisurely review away from the freeway, the most useful monitor display appears to be the one providing the most information--that is, four views of the suspect vehicle. To provide these four views, an eye-level camera (Camera 4 in Exhibit 1.1) should be added to the three-camera display.

Cost. The cost of purchasing a fully outfitted van carrying four color cameras and the required monitors and auxiliary equipment is estimated to be $108,000. This includes the cost of the van itself and California sales tax. The van must be attended at all times by two experienced operators, since frequent camera adjustments are required to deal with glare and changes in ambient lighting. The services of a van and experienced operators can be leased for roughly $5,000 per peak commute period.

1.3.2 Accuracy

Buffer Violations. Buffer violators, those drivers who enter or leave the HOV lane illegally by crossing the double yellow line where lane changing is not allowed, were easily identified by the camera recording oncoming traffic. Violator sightings were unambiguous, and the license plates of those drivers entering the lane are recorded by the video surveillance system.

Occupancy Violations. Videotape reviewers cannot currently identify the number of vehicle occupants with enough certainty to support citations for HOV lane occupancy violations. In early tests with three cameras located on an overpass, subsequent videotape review produced a false alarm rate of 21%. That is, 21% of those vehicles identified as violators by videotape reviewers which had been checked by officers on site actually had the required number of occupants. In later tests with the third camera moved to the freeway itself, the false alarm rate rose to 51%. The chief cause of false alarms appeared to be small children and sleeping adults located out of the view of all three cameras.

Ambiguous Observations. Ambient lighting conditions, glare, and such vehicle design features as tinted windows, headrests, windshield posts, and high windows also made it difficult to interpret the number of videotaped vehicle occupants consistently. Videotape

reviewers reported that these conditions made it impossible to estimate the occupancy of 11.4% of the vehicles passing by the video cameras. Even allowing for these uncertainties, individual reviewers differed widely in their attempts to document vehicle occupancy levels. These differences suggest that tape reviewers must be well-trained to ensure that certain conditions (i.e., glare) do not trigger false alarms and that ambiguous views are treated consistently by all reviewers.

Roadside Occupancy Counts. It is difficult to draw general conclusions regarding the accuracy of roadside counters from the observations of a small number of crews, since it is possible that the observations of different roadside observers will vary as greatly as those of different videotape reviewers. It appears, however, that roadside counters tend to overstate the number of HOV lane violators. In addition, one set of counters clearly understated the number of 3+ vehicles passing the observation point (this was the highest number of occupants required by their count sheets). Another set of counters using different count sheets apparently overstated the number of 6+ vehicles. Their count sheets included a space for 6+ vans, which they filled by assuming that most of the vans passing their observation point had six or more occupants.

It appears that videotape, with the opportunity it affords for rewinding and reviewing questionable vehicles, has the capability of supporting more accurate occupancy counts than those provided by roadside observers who must make decisions on the spot about cars moving past at 50 or 60 miles per hour.

1.3.3 Potential Applications

Although it is technologically possible to record a series of accurate views of vehicles traveling in mainline HOV lanes, no combination of recorded views currently provides enough information to support prosecution for occupancy violators. Even so, videotape surveillance of HOV lanes can provide useful information for a variety of other purposes. These include:

1. **Support for on-line enforcement.** In cases where there are no refuge areas adjacent to mainline HOV lanes, videotape surveillance provides a means of alerting officers stationed downstream from the cameras to the presence of oncoming violators.

2. **Support for remote ticketing.** Although videotape by itself does not appear to be accurate enough to provide a basis for citations, the combination of videotape and an observing officer could conceivably provide the accuracy needed for a system of mailed warnings and citations. If a system of mailed warnings or citations

can be installed, the officer would not have to pursue violators, and a videotape record of driver, occupancy, and license plate would be available for court hearings. Such a system would be more cost-effective than the current system of freeway pursuit and roadside citing, and will reduce the congestion caused by rubbernecking.

3. **Performance Monitoring.** There are several applications in which videotape surveillance appears to provide a marked improvement over current practice. These include:

   (a) **Freeway monitoring** to document vehicle type and occupancy over time;

   (b) **HOV lane monitoring** to document occupancy and violation rates as an aid for enforcement planning; and

   (c) Project evaluation to document the impact of HOV lanes and other carpool incentives on occupancy rates.

The cost of videotaping HOV lane activity is more than double the cost of monitoring operations manually. However, videotape provides more accurate records, a consistent data base, and a permanent, verifiable record of traffic activity. It also provides information on the vehicle mix, traffic speed, and the license plates of carpoolers and suspected violators.

1.3.4 Public Reaction

In a state in which radar cannot legally be used to enforce speed laws on state freeways, videotape surveillance of HOV lanes has significant legislative and public relations implications. These implications are beyond the scope of the current study. However, two pieces of information related to the current study may shed some light on the potential reactions of the public and the media to the possibility of videotape surveillance.

Focus Group Reactions. In a previous study (Billheimer, 1990) focus group participants were asked their opinions of a ticket-by-mail system supported by video surveillance. This possibility generated heated discussion, and driver opinion split dramatically, but evenly, on the desirability of videotape surveillance and tickets-by-mail. Opponents cited “big-brotherism” while proponents argued that freeway ticketing caused significant traffic slowdowns. Most drivers agreed that the public would have to be educated regarding the need both for HOV lanes and mail-out citations if such a procedure were to succeed.

Press Coverage. The field tests undertaken during the current study attracted the attention of the Los Angeles media and resulted in a limited amount of press coverage. Articles in the Los Angeles Times and Ontario Daily Report/Progress Bulletin were both balanced and

informative. To the extent that these stories can be viewed as an indication of press and public reaction to the use of videotape in HOV lane enforcement, there was no suggestion that CALTRANS and the CHP would be exposed to a massive public outcry if videotape proves to be technologically and legally feasible as an enforcement tool. Furthermore, it can be assumed that the articles themselves made potential HOV lane violators in the Los Angeles area more cautious.

1.4 CONCLUSIONS

1.4.1 Enforcement

- Videocameras operating alone cannot currently identify the number of vehicle occupants with enough certainty to support citations for HOV lane occupancy violations. While certain HOV lane infractions, such as illegal buffer crossings, can be identified unambiguously and the license plates of violators can be recorded accurately, the rate of false alarms encountered in using videotape records to document occupancy violations is much too high to support enforcement actions. The chief problem encountered involves the size and positioning of vehicle occupants. Small children and sleeping adults can regularly escape the camera's eye.

  Other problems encountered in attempting to document vehicle occupancy through video surveillance included glare, ambient lighting conditions, vehicle size and position, tinted windows, and sight-obscuring headrests and windshield posts. These other problems, however, do not appear to be insurmountable. Some (i.e. glare and ambient lighting) can be solved technologically through the use of filters and continuous camera adjustments. Others simply lead to indeterminate occupant counts which would not trigger a citation. In any case, these problems are not the kind which lead to the mis-identification of violators. They may cause some violators to escape detection, but they should not produce false alarms so long as the videotape is carefully interpreted.

- Video cameras operating in conjunction with officer observation may provide sufficient accuracy to support mail-out citations for HOV lane occupancy violations. An officer stationed downstream from the video cameras is in a position to verify the occupancy of vehicles which appear suspect to observers monitoring camera output. If a system of mail-out warnings or citations can be installed, this officer would not have to pursue violators, and a videotape record of driver, occupancy, and license plate will be available for court hearings. This system is not foolproof, since the roadside officer may fail to see a small child missed by the video monitor, but it appears to have considerable promise. Moreover, the presence of an observing officer may remove some of the "Big Brother is watching" stigma from the use of videotape.

  Analysis suggests that a combined system of video recording, officer observation, and citations-by-mail is far more cost-effective than the current system of freeway pursuit and roadside citing. The combined video/observation system should be able to produce the same number of tickets for less than one-third the cost of special overtime assignments to roadside enforcement. Furthermore, by eliminating the need to pursue and cite violators during rush hour, the combined system improves the safety of both officers and drivers and reduces the congestion caused by rubbernecking.

- The use of videotape as a real-time on-line enforcement aid appears to be limited to those locations lacking a median shoulder or enforcement area where an officer can be posted for observation purposes.

  The use of videotape as an aid in enforcement activities requiring officer pursuit and on-line citations appears to be somewhat limited. An officer stationed beside an HOV lane in an enforcement area is in a better position to observe violators than an officer stationed in the control van watching a video monitor. Furthermore, the roadside presence of an officer in an enforcement area can have a cautionary effect on drivers. Either officer can radio ahead to pursuit units.

  The only locations where an officer in the videotape van might be better able to assist on-line enforcement than an officer on the freeway would be those locations where there is no refuge area adjacent to the HOV lane. If there is no median shoulder or enforcement area where an officer can be situated for enforcement purposes (as in the case, for example, on Marin 101), video-assisted enforcement stops might be considered as an option.

6.1.2 Surveillance

- Individual interoretation of occupancy levels by both roadside observers and videotaoe reviewers varies widelv with the individual and the instrument used. Evidence suggests that roadside observers overstate occupancy violations. While some observers understated the number of vehicles with three or more occupants, others using different count sheets overstated the number of high occupancy vans carrying six or more people.

- Videotape provides a freewav monitoring tool which is ootentiailv more consistent and accurate than existing techniques for documenting vehicle occupancv. In addition, videotape provides a permanent, verifiable record of the vehicle mix, traffic speeds, and the license plates of violators and carpoolers.

1.5 RECOMMENDATIONS

In view of the improved accuracy of videotape surveillance and the potential promise of videotape as an enforcement tool if used in conjunction with officer observation, it is recommended that CALTRANS and the CHP take the following steps to explore further the potential uses of videotape in HOV lane surveillance and enforcement.

- Test the relative accuracy of a four-camera set-up in conjunction with an observing officer. Further field tests should be undertaken to explore the relative accuracy of a four camera set-up in a freeway setting. As in past field tests, a downstream officer should verify the occupancy of suspect vehicles. However, as an additional check on the accuracy of the officer/videotape combination, motor officers should be available to pursue and cite vehicles identified as violators by both the videotape observers and the verifying officer.

- Test the impact of mailed warnings on violation rates. Video surveillance should be used in conjunction with a roadside officer to monitor several days of HOV lane operations. Written warnings should be mailed to the registered owners of vehicles identified as violators by both the videotape monitors and roadside officers. The impact of this activity on HOV lane violations should be documented through subsequent videotape surveillance and follow-up surveys. Media support for the demonstration should be enlisted through a carefully designed program of public information.

- Explore the use of videotape on ramp meter bypass lanes. The current study has tested and demonstrated the use of videotape in documenting violation activity on mainline HOV lanes. Similar tests should be undertaken on ramp meter bypass lanes.

- Continue to explore the legislative/legal ramifications of mail-out citations. The CHP should continue to explore the necessary legislative and legal steps necessary to support the use of tickets-by-mail for HOV lane infractions.

- Continue to explore the uses of advanced videotape technology in HOV lane surveillance and enforcement. Two additional avenues of investigation identified through the current research include:

    1. The use of micro-cameras installed in the helmets of motorcycle officers; and

    2. The use of low level infrared lighting installed at freeway level to document the occupancy of departing vehicles under conditions of darkness or low visibility.

2.0 INTRODUCTION

2.1 BACKGROUND

Enforcement of California's mainline HOV lanes currently requires a substantial commitment on the part of the California Highway Patrol. A recent SYSTAN study (Billheimer, 1990) estimated that the personnel costs required to enforce the mainline HOV lanes in place in January 1990 exceeded $400,000 per year. HOV lane enforcement has other costs as well. Heavy enforcement during peak commute periods, when violations are heaviest, leads to rubbernecking which can cause traffic flow to deteriorate.

It has been suggested that using video equipment to assist in HOV surveillance and enforcement could reduce the requirements for patrol officers, increase citation rates, and minimize freeway disruption. It is also possible that a videotape of HOV lane activities could improve the accuracy of occupancy counts, provide a permanent record of violations, document the identity of violators, and supply a basis for mail-out warnings or citations. Manufacturers of video equipment claim that it is possible to videotape both the license plates and the windows of vehicles using HOV lanes, even when those vehicles are traveling at rapid rates of speed. What is less well understood is the ability of the video camera to document with certainty the exact number of vehicle occupants. The current investigation is designed to extend past studies of HOV lane enforcement by testing both the feasibility and accuracy of the use of video equipment in HOV lane surveillance.

2.2 OBJECTIVE

The current investigation has been designed to demonstrate and test the use of video equipment in determining vehicle occupancy, documenting violator identity, and aiding enforcement of HOV lanes.

2.3 SCOPE

As many as four high-speed color video cameras operating from a special mobile video unit were used in the demonstration. This equipment was installed by Advanced Technology Division (ATD), and was adjusted to detect vehicle occupancy. Preliminary experiments tested

the effect of different camera positions, filter adjustments, and monitor displays. Once a promising combination of camera positions and displays was identified, they were tested in specific HOV lanes in Southern California. During the tests, trained observers were stationed at the roadside to provide manual counts of violations at the same time that the video equipment was recording. In addition, CHP officers stationed downstream from the mobile video unit were asked to observe selected video-identified violators to ascertain the actual number of occupants in the vehicle and possibly issue a citation. The results of these tests were then analyzed to determine the feasibility, accuracy, and cost effectiveness of using video cameras in HOV lane surveillance and enforcement.

2.4 SCHEDULE OF FIELD TRIALS

A schedule of the field trials undertaken in the current study appears in Exhibit 2.1. Chapter Three details the demonstration activities undertaken during these trials, while Chapter Four analyzes test results and lists the lessons learned from the field demonstrations. Chapter Five discusses potential applications of video technology in HOV lane surveillance and enforcement. Chapter Six outlines recommendations resulting from the current study.

EXHIBIT 2.1

SCHEDULE OF FIELD TRIALS

DATE	ROADWAY	LOCATION	EQUIPMENT	TEST PERSONNEL	PURPOSE OF TEST
8/22/89	Simi Valley Roadway	Winnetka Overcrossing	Mobile van with four high-speed color video cameras; two monitors; two 3/4" recorders	Three technicians	Test alternative camera positions, filter and lens settings, and monitor displays
10/19/89	LA 91 HOV Lane	Wilmington Ave. Overcrossing	Mobile van with three high-speed color video cameras; two monitors; two 3/4 recorders; time generator	Three technicians; Two motor officers; One patrol officer	Test alternative camera positions; use of video in on-line enforcement; accuracy of video sightings
11/12/89	Simi Valley Freeway	Winnetka Overcrossing	Mobile van with three high-speed cameras; one micro-camera; one monitor; one 3/4" recorder	Three technicians	Test alternative lens and filter settings; camera levels; and placement techniques for freeway-level camera
12/14/89	DeSoto Avenue	Intersection of DeSoto and Victory	Micro-camera, monitor and recorder	Two technicians	Test filter, lens and alternative heights for freeway-level camera
12/19/89	LA 91 HOV Lane	Wilmington Ave. Overcrossing	Mobile van with three high-speed color video cameras; one micro-camera; two monitors: two 3/4" recorders	Three technicians; Two motor officers; One patrol officer; Two vehicle counters	Test alternative camera positions; use of video in on-line enforcement; accuracy of video sightings
1/4/90	OR 55 HOV Lane	Warner Avenue Overcrossing	Mobile van with three high-speed color video cameras; one micro-camera; two monitors; two 3/4" recorders; time generator	Three technicians; Three motor officers; Two vehicle counters	Test alternative camera positions; lens and filter settings; accuracy of video sightings; comparability of manual and video occupancy counts