ort No. FHWA-RD-79-15

NFORCEMENT REQUIREMENTS FOR IGH-OCCUPANCY VEHICLE FACILITIES

December 1978
Final Report

Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

Prepared for
FEDERAL HIGHWAY ADMINISTRATION
Offices of Research & Development
Traffic Systems Division
Washington, D.C. 20590

FOREWORD

This report reviews the enforcement problems associated with the operations of priority techniques for high occupancy vehicles (HOV). The report should be of interest to enforcement officials, highway designers, traffic engineers, and legislators who are considering the implemention of preferential treatments for carpools and buses.

From the review of the enforcement operations of 16 HOV facilities the researchers developed a set of enforcement guidelines for both freeway and arterial applications. These guidelines include highway geometrics and traffic control devices needed to aid the enforcement procedure as well as the enforcement execution itself. Several innovative enforcement techniques are reviewed along with the legal implications associated with these techniques. Model legislation has been developed to overcome some of the legal enforcement restraints for HOV priority facilities.

One copy of this report is being sent to each FHWA regional office, FHWA division, and State highway agency. The division and State copies are being sent directly to the division office.

Charles F. Scheffey
Director, Office of Research

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-RD-79-15		

4. Title and Subtitle

ENFORCEMENT REQUIREMENTS FOR HIGH-OCCUPANCY VEHICLE FACILITIES

5. Report Date
December 1978

6. Performing Organization Code

8. Performing Organization Report No.

7. Author(s)
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P.O. Box 600028
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10. Work Unit No. (TRAIS)
32D4-554

11. Contract or Grant No.
DOT-FH-11-9240

12. Sponsoring Agency Name and Address
U.S. Department of Transportation
Federal Highway Administration
Office of Research and Development
Washington, D.C. 20590

13. Type of Report and Period Covered
Final Report
February 1977 and December 1978

14. Sponsoring Agency Code

15. Supplementary Notes Serving as special consultants to Beiswenger, Hoch and Associates were Joseph Wattleworth, Ken Courage, Charles Wallace, William Bopp and Joel Gustafson.

The FHWA contract manager for this research was Howard Bissell (HRS-33)

16. Abstract

Enforcement of high-occupancy vehicle (HOV) traffic restrictions forms an intergral and sometimes critical element of HOV preferential treatment projects. This research 1) reviewed enforcement on HOV facilities, 2) identified effective HOV enforcement techniques, 3) developed model legislation for effective HOV enforcement and 4) prepared HOV enforcement guidelines. This report presents the findings of this research.

Sixteen projects in the United States encompassing each type of freeway and arterial treatment, were visited to gain in-depth operational and enforcement data on each project. These projects exhibited varying enforcement programs, deficiencies and performance levels. Enforcement guidelines have been prepared for each type of freeway and arterial priority treatment of high-occupancy vehicles.

In order to improve enforcement of HOV facilities, innovative techinques — involving photographic instrumentation, mailing of citations, tandem (team) patrol and para-professional officers — have been identified within the context of this research.

For these innovative enforcement techniques to be effective, a compatible legal environment is necessary. This research conducted a legal review of six prominent legal issues posed by these techniques. Model legislation is drafted to provide the proper legal environment for effective HOV enforcement.

17. Key Words
HOV, High Occupancy Vehicle
Bus/Carpool
Preferential Treatment
Transportation Systems Management
Traffic Law Enforcement

18. Distribution Statement
Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	238	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

The authors are sincerely appreciative of the extensive support given to this research project by numerous individuals. Serving as special consultants for this research were Messrs. Joseph Wattleworth (Chapters 3 and 4), Charles Wallace (Chapters 3 and 4), Kenneth Courage (Chapter 6), William Bopp (Chapters 3 and 6) and Joel Gustafson (Chapter 7). Each consultant also reviewed the entire final report.

Mr. Howard Bissell (HRS-33), serving as the FHWA contract manager, provided the overall direction and review of this research, which was well appreciated.

Special thanks are extended to Diane Brown, Carol Gittleman and Jacque Lewis for their patience and excellent skills in typing and editing the many interim and draft reports as well as this final report.

Lastly, the authors wish to express our gratitude to the many individuals and agencies who assisted in this research by providing insights and data on their particular HOV project. The principal individuals were:

Shirley Highway, Fairfax County, Virginia

Mr. John Nesselrodt, Virginia Department of Highways and Transportation
Mr. Charles Abrams, JHK and Associates, Counsulting Engineers
Sargent H. D. Sargent, Virginia State Police

San Bernardino Freeway, Los Angeles, California

Robert Tomlinson, James Bell, Robert Noad, Hank Harada, Andrew Zeilman and Harry Kishineff, California Department of Transportation, District 7
Lt.William Russell, California Highway Patrol

I-95, Miami, Florida

Stan Cann and Marc Lopatin, Florida Department of Transportation
Lt. Ray Grimes, Florida Highway Patrol

Route 101, Marin County, California

Leonard Newman, Edward Graham and James McCrank, California Department of Transportation, District 4
Lt. Richard O'Brien, California Highway Patrol

Banfield Freeway, Portland, Oregon

Don Adams and Max Clotz, Oregon Department of Transportation
Lt. Schroeder, Captain Mark Kezar and Captain E. Brand, Oregon State Police

Ramp Metering Bypass Ramps, Los Angeles, California

Robert Tomlinson, Gary Bork, Robert Cashin, Andrew Zeilman and Harry Kishineff, California Department of Transportation, District 7
Lt. William Russell, California Highway Patrol

North Central Expressway, Dallas, Texas

Bob Whitson, City of Dallas Traffic Operations Division
Jim Carvell, Texas Transportation Institute
Captain W. Cannaday, Dallas Police Department

I-35 W, Minneapolis, Minnesota

Glen Carlson, Minnesota Department of Transportation
Captain Richard Baumann and Captain Borchart, Minnesota Highway Patrol

San Francisco-Oakland Bay Bridge Toll Plaza, Oakland, California

Leonard Newman, Edward Graham and Scott MacCalden, California Department of Transportation, District 4
Captain Jack Hughes, California Highway Patrol

Nicollet Mall, Minneapolis, Minnesota

Greg Finstad, Dick Smith and Dave Koski, Minneapolis Public Works Department
Lt. George Conn and Marie Beauchamp, Minneapolis Police Department

U.S. 1/South Dixie Highway, Miami, Florida

Harry Rose and Ellen Casebeer, Dade County Office of Transportation Administration
Stan Cann and Marc Lopatin, Florida Department of Transportation
Bob Pearsall and Red Wooten, Dade County Metropolitan Transit Authority
Captain Heller and Sgt. Bogolub, Dade County Public Safety Department
Lt. Neil Garfield, Miami Police Department

Washington, D. C. CBD Streets

Tom Durkin, Anthony Rachal, Ken Epstien and David Hammers, Washington, D.C. Department of Transportation
Captain Brian Traynor, Washington, D.C. Police Department

Elm/Commerce Streets, Dallas, Texas

Bob Whitson, City of Dallas Traffic Operations Division
Captain W. Cannaday, Dallas Police Department

N.W. 7th Avenue, Miami, Florida

Stan Cann and Marc Lopatin, Florida Department of Transportation
Kevin McNaughton, Dade County Department of Traffic & Transportation
Bob Pearsall and Red Wooten, Dade County Metropolitan Transit Authority
Lt. Neil Garfield, Miami Police Department
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Marquette/Second Avenues, Minneapolis, Minnesota

Greg Finstad, Dick Smith, and Dave Koski, Minneapolis Public Works Department
Lt. George Conn, Minneapolis Police Department

Ponce de Leon/Fernandez Juncos Avenues, San Juan, Puerto Rico

Edwin Cuebas, Haydee Anton and Elvin Riuz, Department of Transportation and Public Works

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LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
BD	both directions
CBD	central business district
CHP	California Highway Patrol
DOT	Department of Transportation
EB	eastbound
FHWA	Federal Highway Administration
HOV	high occupancy vehicle
HOVL	high occupancy vehicle lane
IB	inbound
kph	kilometers per hour
min/km	minutes per kilometer
min/mi	minutes per mile
mph	miles per hour
MPM	million person-miles
MUTCD	Manual on Uniform Traffic Control Devices for Streets and Highways
MVK	million vehicle-kilometers
MVM	million vehicle-miles
NB	northbound
OB	outbound
PDO	property damage only
pph	persons per hour
SB	southbound
3 ppv	three persons per vehicle
2 ppv	two persons per vehicle
UMTA	Urban Mass Transportation Administration
WB	westbound

CHAPTER ONE

INTRODUCTION

Presently, the number of high-occupancy vehicle (HOV) preferential treatment projects is increasing. This trend is a result of the proven success of the early priority projects, an increasing awareness of the people-moving capabilities of transportation systems, and an evolving emphasis on energy conservation. This trend has recently been accelerated through the philosophy regarding transportation system management (TSM) that was established by the U.S. Department of Transportation in 1975. Transportation officials in urban areas are increasingly investigating travel corridors (involving freeway, arterial and even local street travel) where such projects can be implemented. As diversification in the design of HOV preferential treatment projects continues, the issue of enforcement of HOV facilities takes on greater importance, and the need for developing enforcement strategies which involves a systematic approach to violator apprehension becomes essential. In short, HOV project engineering must involve a planning component for traffic enforcement.

A number of HOV projects have experienced sub-optimal levels of enforcement. This is due in part to a lack of engineering concern with enforcement, even though the enforcement issue has a considerable impact on the operational and safety characteristics of HOV projects, especially those where significant modifications to existing traffic patterns occur.

Adequate traffic enforcement is indeed a key factor in the development of a viable, safe and successful HOV preferential treatment project. Unfortunately, no guidelines were available prior to this report for the purpose of assisting local communities in developing a successful enforcement program for a proposed preferential treatment project. A survey of the recent literature available on the subject yields virtually no exclusive assessment of the implications of the HOV enforcement issue.

The objectives of this research entitled "Enforcement Requirements for High Occupancy Vehicle Facilities" are to:

1. Determine enforcement guidelines for freeway and surface street operations for facilities which provide preferential treatment for high occupancy vehicles; and

2. Provide model legislation to permit the application of effective enforcement techniques for states where existing laws limit or constrain the development of effective enforcement procedures and technologies.

To satisfy these objectives, the following four research activities were undertaken:

1. A review of existing enforcement procedures on HOV facilities and identification of effective existing HOV enforcement techniques and procedures.

2. A review of current state-of-the-art enforcement tactics and technologies and an identification of potential enforcement innovations that may be applied to HOV facilities.

3. An examination of the legal issues pertaining to effective HOV enforcement operations and a preparation of model legislation needed to ensure the legal viability of the enforcement strategies recommended.

4. A preparation of recommendations and guidelines which establish effective means of enforcement for HOV facilities.

Sixteen HOV projects, in all, were visited by the research team. These projects are listed, and key features of each are identified in Table 1. These projects encompasses virtually every type of preferential treatment strategy currently deployed in the United States on both arterial and freeway facilities. For each HOV project and each attendant enforcement program surveyed, operations and enforcement data were collected and analyzed. In many cases, statistical information and/or quantitative data were scarce, or non-existent. For example, record-keeping procedures of most enforcement agencies were insufficient for the purpose of extracting "manpower expended" and "HOV citations issued" for any given period of time on a specific HOV project. However, a broad spectrum of highly relevant and useful qualitative information was readily obtainable. This information can be used to paint a vivid portrait of the experience to date relating to the HOV enforcement issue.

The primary purpose of this report is to document the findings of this research in a manner conducive to assisting local agencies in their efforts to plan an effective enforcement program for any type of HOV project which they may be contemplating. For the benefit of the reader, this manual is organized into a framework that roughly parallels the sequence of needs of an HOV traffic law enforcement planner: Chapter 2 sets forth a basic structure and suggests a policy framework for the HOV enforcement planning process; Chapter 3 provides introductory material with respect to the enforcement elements of HOV projects; Chapters 4 and 5 concentrate on individual HOV priority treatments for freeway and arterial street facilities respectively; Chapter 6 deals with potential innovative enforcement techniques for HOV environments; Chapter 7 presents a treatise on the legal issues associated with HOV enforcement; and Chapter 8 summarizes the conclusions of the first seven chapters.

Throughout this report, reference will be made to various HOV projects investigated during the course of this research. Table 1 shows where additional descriptive information concerning the physical and operational character of each project is provided in the report. Readers who are unfamiliar with these projects may wish to refer to these pages prior to, or during, the review of this document.

TABLE 1

HOV PROJECTS INCLUDED IN ENFORCEMENT RESEARCH

PROJECT/LOCATION	FREEWAY					ARTERIAL				PROJECT DESCRIPTION
	Separate Roadway	Concurrent Flow Lane	Contraflow Lane	Ramp Metering Bypass	Toll Plaza Lane	Separate Facility	Concurrent Flow Lane	Contraflow Lane	Bus Preemption	
Shirley Highway, Washington D.C.	●									page 53
San Bernardino Freeway, Los Angeles, California	●									53
Interstate 95, Miami, Florida		●								65
Banfield Freeway, Portland, Oregon		●								65
Route 101, San Francisco, California		●	●							65/81
Ramp Metering Bypass Ramps, Los Angeles				●						95
North Central Expressway, Dallas, Texas				●						95
Interstate 35W, Minneapolis, Minnesota				●						95
San Francisco/Oakland Bay Bridge, California					●					107
Nicollet Mall, Minneapolis, Minnesota						●				120
Elm/Commerce Streets, Dallas, Texas							●			127
Washington CBD, Washington D.C.							●			127
U.S. 1/South Dixie Highway, Miami, Florida							●	●		127/141
Marquette/Second Avenues, Minneapolis, Minnesota								●		141
Ponce de Leon/Fernandez Juncos Avenues, San Juan, Puerto Rico								●		150
N.W. 7th Avenue, Miami, Florida								●	●	141/158

CHAPTER TWO

THE ENFORCEMENT PLANNING PROCESS

SETTING OBJECTIVES

Setting of goals and objectives are key ingredients in any planning process. The goals and objectives are viewed as a cornerstone of the enforcement planning process since they will form the framework for all subsequent decision-making. The objectives should be operationally-oriented and measurable at some future point in time. In certain instances, the development of goals and objectives will be constrained by a limiting factor. For example, if the funds available for the enforcement program are limited, this constraint imposes the goal of minimizing enforcement costs. The task of establishing objectives must be an iterative process, in that initial objectives may later be determined to be infeasible. For example, it may be impossible to achieve a violation rate of one to five percent on a particular HOV project within the current state-of-the-art with an HOV enforcement budget of $100,000 per year. In such a circumstance, the objective may have to be down-graded to realistic levels, or additional resources found to overcome the discrepancy. For this possibility, a cyclical process may have to be used in the establishment of specific measurable objectives.

DEFINING POTENTIAL ENFORCEMENT PROBLEMS

Once the various types of HOV design strategies under consideration have been defined, a careful review of similar project experiences found in this report will enable the planner to identify specific enforcement problem areas for each of the strategies contemplated. In addition, unique enforcement characteristics inherent in the HOV design strategies should also be explored. The potential impact of each HOV design strategy upon enforcement operations should be estimated.

In selecting a final HOV design strategy for implementation, the enforceability of that concept should be taken into consideration. For each HOV design strategy, the project planning and design team should ask themselves, "How difficult will it be to enforce the restrictions associated with each of these strategies?" Possible modifications to the HOV design strategies should be explored to alleviate as many potential enforcement probelms as possible. The concept of enforceability can be assessed in a number of ways, including public acceptability, costs (in terms of manpower and dollars), and probability of success.

Traffic law enforcement personnel should be intimately involved in this phase of the planning effort to obtain their valuable insight into the nature of possible enforcement problems that may be encountered, and to gain their support and sensitivity to the constraints within which the transportation engineer has to work. In many cases, compromises may have to be made in terms of the final design concept and/or the desired enforcement program. The constraints within which both the design agency and the enforcement agency must work should be clearly defined and mutually understood.

DESIGNING THE ENFORCEMENT PROGRAM

Once the HOV design concept has been selected from a number of candidate strategies, a compre-

hensive enforcement program should be developed. It is possible that several enforcement strategies, or more specifically several sets of procedures within a given strategy, may be applicable to the realistic enforcement objectives of any given HOV preferential treatment project. Chapter 3 presents a comprehensive description of these possible enforcement alternatives. In order to prevent the number of enforcement alternatives from becoming unweildly, budgetary and manpower constraints can be imposed early in this process to assist in screening out the alternatives which consume resources in excess of those available.

When all of the potential enforcement options are identified, a careful review of the local legal environment and state statutory requirements should be made, particularly if innovative enforcement practices are under consideration. If there is any doubt regarding the legal viability of any enforcement alternative, a legal opinion should be sought to clarify the issue. The time requirements for instituting any necessary legislative changes should be incorporated into the evaluation of enforcement alternatives, since the timetable for making such legislative changes may be greater than the time required for project implementation. If the candidate enforcement program must be implemented upon commencement of the project, then those options which require excessive time for legislative action must be eliminated. This problem can be particularly acute if state statutory requirements must be changed or modified.

Once the alternative HOV enforcement programs have been identified and screened, the process of evaluating each viable alternative can begin. There are two very basic criteria which can be used to judge the performance of the various enforcement options. These are: 1) the projected violation rate, and 2) the projected cost of the enforcement program. The selection of the alternative that produces the best results per dollar invested can be made in a straight-forward manner. Unfortunately, detailed statistical information is sorely lacking to provide a highly scientific process for forecasting the violation rate. However, this report does provide generalized data and information to the extent it could be obtained from various operational HOV projects. This information can be used to make educated judgements with respect to the range of violations that can be expected for different types of HOV facilities and varying types and levels of enforcement applied to those facilities. In view of the fact that the violation rate consequences of the alternative enforcement programs cannot be predicted precisely, it is recommended that upper level or worst case predictions of expected violations be used as a basis for estimating manpower requirements. Again, the experienced judgement of the local traffic law enforcement community is recommended to assist in making this determination.

If the selected enforcement program requires additional funding beyond the levels appropriated for the responsible enforcement agency, it may be necessary to develop a proposal for additional funding from external sources. A discussion of potential funding sources for enforcement of HOV facilities is presented on page 24.

DEVELOPING AN EVALUATION PROGRAM

In view of the lack of precise data on which to base the design of the final enforcement program, it is recommended that an evaluation plan be developed to assure a continuing flow of empirical data and feedback for program optimization. Specific areas relating to HOV lane operations and enforcement operations that should be quantified include:

- the relationship between the number of citations issued and the number of violations occurring
- the interrelationships between the violation rate, apprehension rate and the travel time savings of the HOV lane
- the changes in the violation rate due to changes in the quantitative, qualitative or substantive aspects of the enforcement program

It may be possible to reduce the enforcement level of effort without compromising HOV lane operations and enforcement objectives. In this manner, the cost-effectiveness of the enforcement program is improved through a reduction in costs. Such an alteration in the enforcement program is particularly important if the program has been designed to accommodate a worst case situation that did not materialize.

MANAGING THE ENFORCEMENT PROGRAM

A detailed enforcement manual is highly recommended for effectively managing a complex HOV enforcement program. This manual should provide descriptions on the HOV project, system operations, enforcement procedures and reference information. A detailed enforcement manual will reduce the chances of misunderstandings among project personnel, enforcement officers in the field and enforcement agency management personnel as to the functions and responsibilities of each group. Additionally, in the case of the U.S. 1/South Dixie Highway project in Miami, the enforcement manual in conjunction with other project documentation was instrumental in the dismissal of litigation against the project, since this documentation showed to the judge's satisfaction that the project sponsors had acted responsibly in planning and executing the project. A suggested outline for such a manual is presented in Table 2.

DEVELOPING A PUBLIC EDUCATION PROGRAM

Public awareness is essential in any new enforcement program. As the level of planned enforcement for an HOV project increases, the need and importance of a public education program increases. The public awareness campaign should be an on-going effort that serves, in part, to aid enforcement, not replace it. If the public is made to understand the HOV operating strategy and its restrictions, the tendency to violate may be reduced. Furthermore, enforcement agencies uniformly concur that a public awareness program which notifies the public of enforcement activities increases the effectiveness of the enforcement effort.

In the planning phases of a project, informal and formal public meetings and public hearings are an appropriate forum to discuss the enforcement program, its content and consequences. The public education program can involve varying degrees of expense. The program is generally administered by the agency in charge of overall project management and not the enforcement agency. It may be desirable to prepare and fund a public education program budget, possibly combined with the transit advertising campaign for the project.

Inexpensive techniques available include news releases and conferences, public service advertising, transit advertising space, speakers bureaus, pamphlets or handouts, and banners over the roadway. News releases, news conferences and the speakers bureau can be conducted with no out-of-pocket expenses. Pamphlets, handouts and overhead banners may require a small production cost of approximately $100

to $500. Public service advertising costs nothing to air, however professional production costs may be required. Transit properties can often "trade" advertising space on their buses for TV, radio and newspaper advertising, as well as donate space for HOV enforcement education on the buses themselves. Again, professional production costs may be required.

More expensive techniques include paid TV, radio and newspaper advertising, as well as roadside billboards. These advertisements are costly and generally only the largest HOV projects with budgeted funds for such techniques can make use of them. A 30-second TV commercial—not in prime time—could range from $25 to $1,000. Radio advertising has similar rates, but they generally tend to be somewhat lower. Advertising in a major daily newspaper may cost from $6 to $28 per column inch. Billboard advertising may cost from $500 to $1,500 per month for a major billboard. The actual cost for these advertising media depends on the size of the audience for each technique, as well as other factors.

A public education program can pursue two marketing strategies: target marketing and mass media marketing. Target marketing is directed towards a specific group, in this case the users of the HOV facility. This strategy is the most cost-effective form of advertising. Such techniques available include pamphlets and handouts, banners over the facility, roadside billboards and possible transit advertising. All the users of an HOV facility will not necessarily be included in the target group and some mass media marketing may be desirable. Newspaper, radio and TV coverage and advertisements serve this strategy. Peak-hour or "drive-time" radio messages can be a most effective form of this mass media communication.

The primary message that should be transmitted with respect to HOV enforcement education should be a simple statement of: 1) what the law states and what is prohibited, 2) what will be done if a violation of that law occurs and 3) what the consequences are if a violator is apprehended or cited. Other messages may be integrated into this, including the rationale for the law and appeals for mutual cooperation for the public benefit.

The scheduling of the public education program has three components: an initial introductory period, a "blitz" campaign surrounding the opening of the HOV project, and a follow-up period. The introductory period can take place several months prior to the opening of the HOV project and serve to introduce the project. The blitz campaign occurs the week before and week after the opening of the project where a saturation of coverage, to the extent practical, is desired. The majority of paid advertising should occur during this blitz period. The follow-up period serves to reinforce the public education accomplished in the prior two periods. This period should be an on-going effort and the level of effort be dependent upon the perceived need and benefits of the public education program for HOV enforcement. It may be desirable to include the follow-up message for enforcement with the transit or overall project advertising campaign for the HOV project.

TABLE 2

SUGGESTED ENFORCEMENT PLAN OUTLINE[1]

I. DESCRIPTION OF PROJECT

A. Brief statement of objectives of project and purposes of project elements. List participating agencies and outline their responsibilities.

B. Physical Features
   1. Cross-sectional diagrams showing lane configuration
   2. Map of project area
      a. show clearly geographic boundaries and jurisdictional limits if more than one enforcement agency is involved
      b. show location of special traffic procedures and/or restrictions (e.g. no left turns or special crossover signals for buses to enter contra-flow lane)

II. SYSTEM OPERATIONS

A. Operating Policies--This section should clearly and concisely deal with operating regulations. These might include:
   1. How many vehicle occupants constitute a carpool?
   2. What types of vehicles will be granted priority? (municipal buses, inter-city buses, emergency vehicles, taxis, trucks, etc.)
   3. Restrictions should be clearly defined, for example, only passenger vehicles having 3 or more occupants will be allowed to use priority lanes.

B. Operating Hours--Specify times of project operation, distinguishing between various elements if necessary. State policy on holidays and define procedures for individual officers to be apprised of special circumstances, for example, "project operates during State holidays, but not on National holidays."

C. Personnel Levels--Briefly specify nature of agreement between enforcement agency and project sponsoring agency.
   1. Are there a certain number of officers to be assigned specially to the project or is this to be included in routine patrol duty?
   2. If specially assigned, are any officers to remain at particular intersections throughout project hours?
   3. If special services such as police helicopters will be used, instruct enforcement personnel on how to contact these services.

III. ENFORCEMENT PROCEDURES

Project sponsors should understand that no matter how specifically procedures are spelled out, individual officers will often have to rely upon their own judgement, particularly in emergencies. However, in order to maximize the effectiveness of those officers, certain guidelines should be established.

A. Routine Enforcement Procedures--Detail specific procedures for enforcement, relating them to various project elements.
   1. Violations--Outline general categories of violations to be expected and the penalties for each.

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1. Urban Consortium for Technological Initiatives, A Manual for Planning and Implementing Priority Techniques for High Occupancy Vehicles, Technical Guide, United States Department of Transportation, July 1977.

TABLE 2 (CONT.)

2. Standard Operating Tactics--This section should cover routine enforcement procedures, such as:
   a. whether violators are to be pulled off the roadway or reports of violators radioed ahead to officers "downstream" (depends on average speed, level of congestion, level of enforcement manpower, etc.)
   b. if project involves priority lanes with special entry/exit points, the role of the officer assigned to each location
   c. special activities related to beginning or ending daily project operations, e.g. special escort for signing crews or "flushing" the lane

B. Procedures for Possible Malfunctions--This section should cover malfunctions of various project elements. Information should include:
   1. Bus breakdown
      a. removal of disabled buses (whether next bus should push immobile vehicle to storage area or towing company or emergency crew should be called, phone number (_____)
      b. notification of transit agency (phone number, whether extra bus available)
      c. procedures for transfer of passengers
      d. rerouting of following buses
   2. Other vehicle breakdown
      a. removal of disabled vehicle
      b. traffic rerouting
   3. Equipment malfunction or damage
      a. list proper agency and phone number for major types of malfunction or damage
      b. list any special interim procedures to be followed until malfunction corrected

C. Emergency Situation Guide
   1. List any departures from normal policy for dealing with accidents and other emergencies.
   2. Give guidelines for determining if project operations must be temporarily halted due to accident or other emergency.

D. Reporting Procedures--Coordinate with evaluation team to see if special reports are to be filed by enforcement officers regarding accidents, vehicle breakdowns, signal malfunctions or other problems and the subsequent action taken by the officer. Explain the purpose for such reports. If a special form is to be used, it should be developed during the planning phase in conjunction with enforcement officials. Include copy of form and any special instructions in enforcement manual.

E. Special Intersection Considerations–If there are significant changes in operating policy planned for particular intersections (rerouting of traffic due to turn prohibitions, changes in signal operations, etc.) small maps of those intersections indicating the new procedures should be provided.

IV. REFERENCE INFORMATION

Even if phone numbers related to various questions or problems are given elsewhere in the text, it is a good idea to have a special section that can be referred to quickly. It should list the situation, person to be contacted and the phone number. For example:

A. Signal Malfunction
   - Mr. Jones - Traffic Engineering Department
     Phone number:

B. Public Inquiries
   - Ms. Smith - Project Coordinator
     Phone number:

CHAPTER THREE

ENFORCEMENT SYSTEMS FOR PRIORITY TECHNIQUES FOR HIGH OCCUPANCY VEHICLES

The enforcement process is a system in which all component steps are undertaken in series. These steps are:

1. detection of the violator,
2. apprehension of the violator,
3. issuance of a citation to the violator, and
4. resolution of the citation.

There are many systems that could accomplish all or part of these steps but, in general, conventional techniques are the most predominant. A discussion of innovative enforcement techniques is presented in Chapter 6.

The first step is the detection of the violator. While photographic techniques or other new technological concepts could be used for this purpose, it is, in general, a police officer that accomplishes this step using direct visual observation.

Next the violator must be apprehended. Again, sophisticated techniques could be considered but, again, the police officer usually issues the citation to the violator upon apprehension.

The resolution of the citation is made in one of two ways:

1. violator pleading "guilty" or "no contest" and paying the fine; or
2. violator pleading "not guilty" and having the judge or administrative officer decide on the guilt and penalty.

This last step is a very important step in the success of the HOV priority projects and underscores the importance of the judicial branch in the successful undertaking of these projects.

The remainder of this chapter contains more detailed discussions on A) existing HOV enforcement programs, B) the HOV legal/judicial environment, C) HOV enforcement problems and deficiencies, and D) HOV enforcement program performance.

HOV ENFORCEMENT PROGRAMS

There are a number of interrelated elements which comprise the HOV enforcement program. These elements are:

1. enforcement strategies
2. enforcement procedures
3. objectives of the enforcement program

4. the priority assigned to the HOV enforcement program
5. assignment of enforcement personnel
6. enforcement equipment
7. enforcement budget and funding
8. enforcement planning

ENFORCEMENT STRATEGIES

Enforcement strategies as related to HOV projects can be organized into three broad categories: "routine," "special," or "selective." Routine enforcement are those enforcement activities which are randomly conducted in concert with the normal assortment of a uniformed police officer's duties. Special enforcement involves police activities planned and applied specifically to the HOV project on a continuing basis. Selective enforcement is a combination of both routine and special approaches, to the extent that special enforcement is applied periodically by officers in conjunction with a routine enforcement program during other periods. Table 3 lists the enforcement strategy applied on each HOV project investigated.

Routine Enforcement

Under a routine enforcement approach, the existence of an HOV project does not significantly alter the enforcement agency's priorities, financing requirements, tactics or objectives. In essence, police officers assigned to patrol zones containing HOV facilities are permitted wide discretion in enforcing violations. The result is often an unequal or random distribution of enforcement effort. Nevertheless, routine enforcement can be an effective approach for a variety of reasons.

The geometric and operational features inherent in the HOV project can often make significant contributions to the routine enforceability of an HOV project. For example, the geometrics of the Interstate 5 exclusive ramp in Seattle during AM operations are such that a violator cannot see any enforcement activity until irrevokably committed to a violation. As a result of this "surprise" element, routine enforcement is successful due to the presence of routine patrols in the vicinity of the ramp terminus. The Nicollet Mall transitway in Minneapolis was developed more for aesthetic reasons than for offering travel time advantages to transit vehicles. Since there is no speed advantage gained from violating the restrictions of the transitway, the incentive to violate is eliminated. Additionally, since only buses are permitted access, a violator using the transitway is conspicuous and is easily detected and apprehended by routine patrols. In both of these situations, routine patrol officers can effectively enforce the priority restrictions within the context of their usual duties, provided that police management takes steps through policy pronouncements to inform its personnel of the importance of aggressive enforcement activity.

Routine enforcement could also be applicable if the violation rate experienced under a routine enforcement environment is considered acceptable or tolerable.[1] If the violation rate of an HOV project is deemed acceptable by project management, then there will be no requests of the enforcing agency for

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1. For further discussion on the subject of violation rate "acceptability" see the section entitled Objectives of the Enforcement Program on page 20.

TABLE 3

ENFORCEMENT STRATEGY BY HOV PROJECT

	PROJECT	HOV CODE*	STRATEGY			RATIONALE FOR ROUTINE STRATEGY			
			Routine	Special	Selective	Self-Enforcing Features	Acceptable Violation Rate	Lack of Funds	Lack of Enforcement Initiative
FREEWAY	Shirley Highway - Washington, D.C.	1			x				
	Interstate 95 - Miami	2	x					x	x
	Banfield Freeway - Portland	2			x				
	Route 101 - San Francisco	2		x					
	Route 101 - San Francisco	3	x			x	x		
	North Central Expressway - Dallas	4			x				
	Interstate 35W - Minneapolis	4	x				x		
	Santa Monica Freeway - Los Angeles	4			x				
	Interstate 5 - Seattle	5	x			x	x		
	San Francisco/Oakland Bay Bridge	6			x				
ARTERIAL	Nicollet Mall - Minneapolis	A	x			x	x		
	Elm/Commerce Streets - Dallas	B	x				x		
	Washington CBD - Washington, D.C.	B	x					x	
	US 1/South Dixie - Miami	B		x					
	US 1/South Dixie - Miami	C		x					
	Marquette/Second Streets - Minneapolis	C	x			x		x	
	Ponce de Leon/Fern. Juncos Aves.-San Juan	C	x			x	x		
	NW 7th Avenue - Miami	D	x					x	
	NW 7th Avenue - Miami	E	x			x	x		

*FREEWAY

1. Separate Roadway
2. Concurrent Lane
3. Contraflow Lane
4. Ramp Metering Bypass
5. Exclusive Ramp/Access
6. Toll Plaza Lane

*ARTERIAL

A. Separate Facility
B. Concurrent Lane
C. Contraflow Lane
D. Reversible Lane
E. Bus Pre-emption

special enforcement activities. In the case of the Elm/Commerce Streets concurrent-flow curb bus lanes (and right-turning vehicles) in Dallas, the application of routine enforcement efforts (foot patrols on downtown zone duty) is uniformly judged as providing an acceptable level of compliance with a violation rate of about 14 percent.[2] This violation rate level does not pose a serious threat to the project's viability since impacts (if any) on bus travel times are insignificant from a ridership standpoint, and no serious safety problems are created by the violators. Moreover, the quantity of violators do not represent a sufficient number to attract an onslaught of complaints or convey a poor image of the project's viability.

Routine enforcement may be the only alternative strategy available if funds do not exist to pay for special or selective enforcement.[3] These strategies require additional enforcement man-hours and vehicle operation resulting in special costs for HOV project enforcement. Since most enforcement agencies believe they operate at undermanned and underfinanced levels, the competition for manpower and funds among the various police activities is intense. Almost uniformly among enforcement agencies, the priority of HOV enforcement is less than the priority of public safety activities and traffic law enforcement involving hazardous vehicle movements.[4] In such a context, it may be impossible for the enforcement agency to allocate special manpower and funds for special or selective enforcement of an HOV project, and thus the HOV project must operate with routine enforcement. The enforcement agency for the NW 7th Avenue reversible lane project in Miami because of budget constraints could not respond to a request by project management for special enforcement. The NW 7th Avenue project for the most part operated with routine enforcement patrols.

The initiative to provide an adequate level of enforcement to the HOV project may be absent within the structure of the enforcement agency since an HOV project places additional responsibilities on the enforcement agency without the requisite increase in funding or personnel. This lack of enforcement initiative could be fostered also by the concern over unsafe vehicle movements associated with the HOV enforcement process (detection, apprehension and issuance of the citation). Rather than provide this additional enforcement, the enforcement agency could be inattentive to the enforcement needs of an HOV project. A contributing factor to this inattentiveness may also be the relative exclusion of the enforcement agency from participation in the planning stages of the project, thereby removing a valuable source of information critical to the "enforceability" of the HOV project during its design phase. The I-95 HOV project in Miami faced this circumstance, as the perceived difficulty and danger of enforcing the HOV lane discouraged in part, the enforcement agency from inaugerating a special or selective enforcement program.

Table 3 displays the reason(s) routine enforcement was deployed on those HOV projects exhibiting such an enforcement strategy.

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2. Throughout this report, the term "violation rate" is expressed as the ratio of the number of violators in the preferential lane to the total number of vehicles in the preferential lane.

3. For further discussion on the funding of HOV enforcement see section entitled "Enforcement Budget" on page 24.

4. For further discussion on the priority of HOV enforcement see section entitled "Priority of HOV Enforcement" on page 22.

Special Enforcement

Special enforcement is characterized by continuing, systematic manpower allocations and enforcement tactics specifically dedicated to enforce HOV violations. A special enforcement strategy is appropriately employed when the need for HOV enforcement is great. In such instances, routine enforcement cannot effectively address HOV enforcement needs without sacrificing other enforcement duties—duties which police management views as equally important as HOV enforcement.

Special enforcement programs can be deployed in several ways. One of these involves reallocating existing forces to the desired HOV enforcement effort. Naturally, this can detract from the quality and quantity of police services offered in surrounding geographic or functional areas of police responsibility. To avoid such sacrifices, the more common method of deploying special enforcement details include the assignment of additional manpower and equipment during HOV project operating hours. This can be accomplished by utilizing existing personnel on an overtime basis, or by hiring additional personnel. The latter option may be an attractive alternative to management, especially when a critical shortage of police personnel exists. It is common practice for the personnel assigned to a special HOV enforcement detail to leave that duty in order to handle other special emergencies such as accident investigation and traffic control. The special enforcement program may be funded from within the existing enforcement agency's budget or have special funds allocated for it by HOV project management.

A special enforcement program is utilized on the U.S. 1/South Dixie HOV project in Miami because of critical enforcement requirements. This program, at one time, consisted of six officers over a 5.5 mile (8.9 km) project length in order to achieve a 5 to 10 percent violation rate. The funds for this program came from the budgets of the transportation agencies and not the enforcement agencies. An agreement between the transportation agency and enforcement agency was enacted defining this special enforcement program.[5]

It is interesting to note that the U.S. 1/South Dixie project enjoys significant success by using a special enforcement strategy whereas the N.W. 7th Avenue reversible lane project, which is located in the same city (Miami) and involved several of the same enforcement agencies, was partly unsuccessful from an enforcement standpoint while utilizing a routine enforcement strategy. There are two major differences on these projects as they relate to enforcement. Project management for the U.S. 1/South Dixie project involved the enforcement agencies in the planning of the project and it offered the enforcement agencies the necessary funds for special enforcement. These measures were not undertaken in regard to the N.W. 7th Avenue project.

Selective Enforcement

Selective enforcement is usually applied periodically to specific problem areas where violations of the HOV facility have been observed. The application of selective enforcement can vary in terms of

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5. Transportation agencies commonly contract for special enforcement efforts (i.e. maintenance of traffic) on construction projects in urban areas. This is generally accomplished through the agency's construction contractor.

time, location and level-of-effort. Because of the temporary nature of the special enforcement activity in a selective enforcement program, the extra enforcement personnel is generally made available by a reassignment of manpower from other duties and does not generally require additional manpower. The overall purpose of a selective enforcement strategy is to induce a high level of motorist compliance by applying routine and special enforcement tactics in an unscheduled manner, thereby not allowing motorists to predict when enforcement will occur.

The degree of formality associated with a selective enforcement program generally increases with the magnitude of the need for HOV enforcement. For example, the selective enforcement program for the Banfield Freeway HOV project in Portland, which exhibited substantial enforcement demands, is highly structured. Selective enforcement activities are formally scheduled and planned well in advance of their execution. On the other hand, the North Central Expressway bus by-pass ramp in Dallas, and the Interstate 35W bus by-pass ramps in Minneapolis have a much lower enforcement requirement, thereby allowing their selective enforcement program to be executed in response to infrequent enforcement requests by project management and/or the public. Similarly, the selective enforcement of the San Francisco-Oakland Bay Bridge toll plaza HOV lanes is employed whenever the violation rate exceeds 10 percent for a period of approximately one week.

ENFORCEMENT PROCEDURES

Overwhelmingly, current HOV enforcement tactics conform to the traditional enforcement procedures utilized in traffic law enforcement - procedures developed prior to the development of HOV facilities. Innovative procedures have generally not been developed and applied to HOV facilities despite this new type of enforcement problem and violator. Enforcement procedures may vary among HOV projects because accepted traffic law enforcement practices consist of a myriad of procedures. HOV enforcement programs consist of procedures for 1) surveillance and detection, 2) apprehension and citation and 3) management approaches. Table 4 summarizes the enforcement procedures utilized for each HOV project investigated.

Surveillance and Detection

Various surveillance and detection procedures focus on the type of enforcement patrol and the visibility of the patrol unit(s). The HOV enforcement program may include one or a combination of the following types of patrol:

- Foot Patrol - enforcement personnel travel by foot.
- Line Patrol - enforcement personnel travel by motor vehicle(s) over a particular roadway section.
- Zone Patrol - enforcement personnel travel by motor vehicle(s) over a zone or a particular area (not limited to a roadway section).
- Stationary Patrol - enforcement personnel and motor vehicles are deployed in a fixed position.

TABLE 4

ENFORCEMENT PROCEDURES BY HOV PROJECT

	PROJECT	HOV CODE*	DETECTION					APPREHENSION/CITATION					MANAGEMENT		
			Foot Patrol	Line Patrol	Mobile Patrol	Stationary Patrol	Hidden Enforcement	Standard Procedure	Stationary Apprehension	Wave-off Violator	Mail-out Warnings	Team Approach	Interagency Approach	Public Info. Campaign	Enforcement Manual
FREEWAY	Shirley Highway - Washington, D.C.	1		x		x		x						x	
	Interstate 95 - Miami	2		x				x						x	
	Banfield Freeway - Portland	2		x			x	x						x	
	Route 101 - San Francisco	2		x		x		x						x	
	Route 101 - San Francisco	3		x		x		x						x	
	North Central Expressway - Dallas	4				x	x		x						
	Interstate 35W - Minneapolis	4		x		x	x	x	x		x	x		x	
	Santa Monica Freeway - Los Angeles	4		x		x		x	x			x		x	
	Interstate 5 - Seattle	5		x	x		x	x					x		
	San Francisco/Oakland Bay Bridge	6	x	x		x		x	x		x	x		x	
ARTERIAL	Nicollet Mall - Minneapolis	A	x							x					
	Elm/Commerce Streets - Dallas	B	x						x	x		x			
	Washington CBD - Washington, D.C.	B			x			x							
	US 1/South Dixie - Miami	B				x			x				x	x	x
	US 1/South Dixie - Miami	C				x			x				x	x	x
	Marquette/Second Streets - Minneapolis	C			x				x	x				x	
	Ponce de Leon/Fern. Juncos Aves.-San Juan	C			x			x						x	
	NW 7th Avenue - Miami	D			x	x		x	x	x			x	x	x
	NW 7th Avenue - Miami	E			x			x							

*FREEWAY

1. Separate Roadway
2. Concurrent Lane
3. Contraflow Lane
4. Ramp Metering Bypass
5. Exclusive Ramp/Access
6. Toll Plaza Lane

*ARTERIAL

A. Separate Facility
B. Concurrent Lane
C. Contraflow Lane
D. Reversible Lane
E. Bus Pre-emption

Foot patrols are generally applicable on HOV projects located in the downtown areas, since foot patrols are often already deployed in these locations and vehicular mobility is often difficult. The disadvantages of a foot patrol often occurs in the apprehension and citation process because of a lack of pursuit capability. The Minneapolis Police Department utilizes foot patrols to enforce the exclusive bus street on Nicollet Mall.

Line patrols are used more often on freeway facilities, whereas zone patrols are more often employed on arterial street networks. This is often due to institutional factors, such as jurisdictional agreements that require the state enforcement agency to patrol the freeway system and the local enforcement agency to patrol the remaining highways and streets within a municipality. Under a routine enforcement strategy, line patrol may benefit the HOV project more than a zone patrol, since a line patrol provides more continuous enforcement visibility. Nominally, zone patrols exhibit only periodic enforcement visibility on an HOV facility. The Shirley Highway (I-395) separate HOV lanes in Washington, D.C. area is enforced by a line patrol, while the Washington, D.C. curb bus lanes uses a zone patrol.

Stationary patrols involve the deployment of enforcement personnel at specific locations. This procedure is associated with a special enforcement tactic and would be most appropriately located at entry/exit points to the HOV lane or locations experiencing a high number of HOV violations. Stationary patrols provide the HOV project with a high level of enforcement visibility. In order to be most effective, stationary patrol units generally need to be positioned in close proximity to a safe and accessible refuge area, in which violators can be apprehended, detained and cited, clear of normal traffic patterns. If such apprehension areas are co-located with the position of the stationary unit, the time consuming element of pursuit can be fully eliminated and violators can be manually signalled or directed into the apprehension/refuge area. The US 1/South Dixie HOV project in Miami effectively uses stationary patrols by converting left-turn bays in the median (left-turns are prohibited during the project's operating hours) into apprehension areas.

Overwhelmingly, surveillance and detection procedures of the HOV enforcement programs are very conventional. The one possible exception would be the deployment of concealed traffic units strategically placed out of sight of prospective violators. Few HOV projects investigated use this approach. It is used only when visible enforcement proves to be ineffective. In a highly visible enforcement environment, the HOV violator can take the necessary evasive maneuvers to avoid apprehension and citation. The Dallas Police Department effectively utilizes concealed traffic units on the North Central Freeway bus by-pass ramp as a key component of its selective enforcement program. Officers on the Santa Monica Freeway in Los Angeles are generally concealed to detect violators of the ramp-metering signals, but at the same time can detect violators of the bus/carpool by-pass of the metered ramps.

Apprehension and Citation

This element of the HOV enforcement process may include one or more of the following apprehension and citation procedures:

- "standard" apprehension and citation
- stationary apprehension
- signal or wave-off of violator
- mail-out of warnings
- team approach or tandem apprehension

The "standard" apprehension and citation procedure is a common practice of enforcement personnel. This involves the pursuit of a violator, followed by apprehension, and then followed by issuance of the citation by a single unit. For HOV projects that incorporate either a line patrol or zone patrol, this procedure is utilized. Occasionally, a stationary patrol assignment will involve this type of approach as is done on the Route 101 HOV project in San Francisco. Enforcement agencies may be reluctant to follow this "standard" procedure if it is considered to have unsafe vehicular movements associated with it. The I-95 project in Miami follows this procedure but the enforcement agency is highly concerned about the fact that traffic density is such that weaving through traffic is difficult, and that once a violator is finally escorted to the outside shoulder, "rubber-necking" by passing motorists creates "shock" waves in the traffic stream which compound the safety problem.

Stationary apprehension is linked with stationary and foot patrols, and it does not involve pursuit of the violator. In a stationary or foot patrol mode of operation, all that is usually necessary is directing the violator to a refuge area. In order to utilize this technique, a highly accessible refuge area must be available to the enforcement personnel. In the case of the San Francisco-Oakland Bay Bridge toll plaza HOV lanes, the refuge area is temporarily made by closing a traffic lane immediately past the toll-booth plaza. Violators who run past the apprehension location are subject to vehicular pursuit.

Signalling or waving-off of a violator from an HOV facility is an alternative to the more common apprehension and citation procedures. This wave-off procedure is accomplished by appropriate gestures (waving of the arm, honking the horn) by the officer to the motorist in violation of the HOV restrictions. The intent here is to inform the motorist of the violation in order that the motorist would then safety exit the HOV lane. There is no apprehension and issuance of a citation with this technique. The wave-off procedure may be utilized for a variety of reasons including 1) conditions unsafe to apprehend the violator; 2) the enforcement personnel have too many other duties at that moment and 3) the violator appears unaware of the HOV signing restrictions. It is common to use the wave-off procedure at the initiation of an HOV project in order to educate the motorists regarding the new traffic operational changes.

The mail-out of official warning citations is a procedure that is infrequently used. The purpose of a mail-out campaign is to eliminate the pursuit/apprehension process and warn a large number of violators with a minimal enforcement effort. Where there are a large number of violators, it may be impossible for enforcement personnel to apprehend a significant number of them by using "standard" procedures. By mailing the owner of a violating vehicle a warning letter or citation (via license plate identification), many more violators can be directly affected by the enforcement program. When, for example, the San Francisco-Oakland Bay Bridge project conducted a campaign of mailing warning letters to HOV violators,

a followup study revealed that 90 percent of the violators, who received such letters, did not immediately repeat as violators.[6,7]

For certain states and municipalities, it is possible for two or more enforcement personnel to work in tandem with each other to apprehend the traffic violator and issue a citation. This procedure is negated in those jurisdictions where, by law, the apprehending officer must also be the officer witnessing the violation. The team approach is generally utilized on HOV projects when it is impossible, or considered unsafe, for a single officer to detect and apprehend a violator. In this case, one officer detects the HOV violation and subsequently informs another officer stationed downstream for the purpose of apprehension. The I-35W bus by-pass ramps project in Minneapolis uses this team approach on ramps where one officer can not effectively perform both the detection and apprehension functions.

Management Techniques

Management approaches for HOV enforcement programs may include 1) an interagency approach, 2) a public awareness campaign and 3) an enforcement manual.

An interagency approach involving two or more enforcement agencies is sometimes used because 1) the HOV facility crosses two or more jurisdictions or 2) more than one level of government (city, county and state) is involved in the HOV project and a sense of cooperation and participation exists. The interagency approach can distribute costs and responsibilities of an extensive enforcement program among several agencies and thereby lessen the manpower and cost impacts on any one agency. The Interstate 5 exclusive ramp in Seattle uses a successful interagency approach involving state and municipal police agencies.

Some form of a public awareness campaign has been employed on almost every HOV project and it is generally implemented by the agency in charge of overall project management and not the enforcement agency. The public awareness campaign can involve any number of items including newspaper articles and advertisements, radio and TV announcements, and handouts to motorists. The public awareness campaign may be an ongoing effort that serves, in part, to aid enforcement, not replace it. If through a public awareness campaign, the public is made to understand and be knowledgeable of the HOV operating strategy and its restrictions, the tendency to violate may be reduced. Furthermore, enforcement agencies commonly agree that a public awareness program which notifies the public of enforcement activities increases the effectiveness of the enforcement effort. The Banfield Freeway HOV project in Portland has experienced extensive public information campaigns regarding its operational strategy and enforcement program.

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6. Enforcement of the Southeast Expressway concurrent-flow HOV lane in Boston, Massachusetts, which is not included in the research for this report, began October 17, 1977, to mail citations to violators of the HOV restrictions. Massachusetts law permits citations for moving traffic violations to be mailed to the registered owner of the vehicle when it is deemed unsafe to apprehend the motorist at the time of the violation. On the first day using this enforcement procedure, over 200 citations were issued. This figure stabilized at around 50 citations per day. The result of this enforcement program was a decrease in the violation rate from 80 percent to 25 percent. The project was terminated on November 2, 1977, due to excessive travel times being experienced in the general traffic lanes coupled with adverse political overtones.

7. For further discussion of the legal issues associated with the mailing of citations to HOV violators, see Chapter 7, "Legal Issues Regarding HOV Enforcement."

The U.S. 1/South Dixie HOV project and the N.W. 7th Avenue reversible lane project, both in Miami, each had an enforcement manual developed by the transportation and enforcement agencies involved in the project. The enforcement manual was issued to the enforcement agencies to assist in the enforcement of the HOV restrictions. This manual outlined in detail the HOV operating strategy, traffic regulations, parking restrictions, procedures for conducting HOV enforcement duties and procedures for handling special situations such as a bus breakdown. The U.S. 1/South Dixie manual was developed prior to the project start-up, whereas the N.W. 7th Avenue manual was developed after the initiation of the project and resembled the well-received U.S. 1/South Dixie manual.[8] The remaining HOV projects also had enforcement procedures—written or oral—developed and issued by the enforcement agency, oftentimes in conjunction with the transportation agency(s) involved with the HOV project.

OBJECTIVES OF THE ENFORCEMENT PROGRAM

None of the HOV projects defined an enforcement objective in specific terms prior to the initiation of the project. This circumstance is not surprising when the uncertainty surrounding motorist reaction to an HOV project is considered, and little or no information is available to predict the effectiveness of planned enforcement strategies. The enforcement objective, whether stated formally or informally, is generally described as: "to maintain the integrity of the HOV project."

Once the HOV projects gain operating experience, some enforcement programs established a specific enforcement objective by defining a "tolerable violation rate." The enforcement program for the Banfield Freeway HOV project in Portland has as an objective, a violation rate that should not exceed the range of 20 to 25 percent of the vehicles using the HOV lane. This violation rate was established subjectively by enforcement and transportation officials as a rate which could be tolerated from the viewpoint of project operations and public acceptance. As long as the enforcement agency could meet this objective, it would maintain complete control over the scheduling of the enforcement activities. By informal agreement, if the violation rate exceeded 25 percent, then the transportation agency could begin to schedule enforcement activities to be conducted by the enforcement agency. Likewise, the transportation and enforcement agencies involved with the U.S. 1/South Dixie HOV project established a violation rate objective of 5 to 10 percent in the carpool lane. This range was thought to be the maximum number of violations allowable in order to maintain a significant travel time advantage in the carpool lane. It is interesting to note that in their respective selective and special enforcement programs, the enforcement programs on the Banfield Freeway and U.S. 1/South Dixie HOV projects are both able to achieve their desired level of compliance. Table 5 shows the enforcement objective associated with each HOV project surveyed.

For the projects that do not have a "tolerable violation rate" quantified, the "tolerable violation rate" is often defined as the violation rate currently being experienced on the project. In other words, the enforcement program and its associated violation rate was deemed tolerable by transportation and enforcement officials associated with the projects. In such circumstances, the constraints—an enforcement agency's available resources, project geometrics and operating environment—form a performance envelope within which the violation rate rests and that rate, in turn, becomes the enforcement objective.

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8. For further information on the U.S. 1/South Dixie manual, contact the Metropolitan Dade County Office of Transportation Administration in Miami, Florida.

TABLE 5

ENFORCEMENT OBJECTIVE/ADDITIONAL REQUIREMENTS/PRIORITY ASSIGNMENT BY HOV PROJECT

	PROJECT	HOV CODE*	OBJECTIVE		ADDITIONAL REQUIREMENTS					PRIORITY		
			Maintain Integrity of HOV Project	Desired Violation Rate (%)	No Parking	No Stopping or Standing	No Left Turn	No Right Turn	24 Hour HOV Operation	Low Priority Routine Enforce.	High Priority Routine Enforce.	High Priority Selective/Special Enforcement
FREEWAY	Shirley Highway - Washington, D.C.	1		5						x		x
	Interstate 95 - Miami	2	x							x		
	Banfield Freeway - Portland	2		20-25							x	x
	Route 101 - San Francisco	2	x									x
	Route 101 - San Francisco	3		0						x		
	North Central Expressway - Dallas	4	x							x		x
	Interstate 35W - Minneapolis	4	x							x		
	Santa Monica Freeway - Los Angeles	4		5-10						x		x
	Interstate 5 - Seattle	5	x						x	x		
	San Francisco/Oakland Bay Bridge	6		5							x	x
ARTERIAL	Nicollet Mall - Minneapolis	A	x		x		x	x	x	x		
	Elm/Commerce Streets - Dallas	B	x		x	x				x		
	Washington CBD - Washington, D.C.	B	x		x					x		x[a]
	US 1/South Dixie - Miami	B		5-10			x					x
	US 1/South Dixie - Miami	C		5-10			x					x
	Marquette/Second Streets - Minneapolis	C	x		x	x			x		x	
	Ponce de Leon/Fern. Juncos Aves.-San Juan	C	x		x				x	x		
	NW 7th Avenue - Miami	D	x		x		x			x		
	NW 7th Avenue - Miami	E		0	x					x		

*FREEWAY

1. Separate Roadway
2. Concurrent Lane
3. Contraflow Lane
4. Ramp Metering Bypass
5. Exclusive Ramp/Access
6. Toll Plaza Lane

*ARTERIAL

A. Separate Facility
B. Concurrent Lane
C. Contraflow Lane
D. Reversible Lane
E. Bus Pre-emption

a. Several streets are "swept" clear of illegally parked cars which are towed away on a daily basis.

Enforcement personnel and traffic engineers frequently raised the issue of whether it is desirable to exclude all violators from using the HOV facility. For most HOV projects, it would be a very expensive proposition to achieve a violation rate of zero percent. Most HOV projects have some unused capacity that could be filled by violating vehicles with the resultant effect of improving traffic flow on the overall facility. For example, if the theoretical optimum occupancy rate[9] on a concurrent-flow priority lane is 2.8 passengers per vehicle and the restriction calls for a minimum of 3 persons per vehicle, then an argument can be made to endorse the position that a small percentage of violators could actually use the HOV lane (in order to lower the average occupancy figure towards the optimum occupancy rate) and avoid any detrimental effect on the HOV program's objectives.

Such a policy of permitting violating vehicles to use the HOV facility needs to be tempered against the negative public reaction arising out of a high violation rate. The I-95 HOV project in Miami experienced violation rates in excess of 60 percent under a carpool restriction of three persons, but yet the free flow status of the HOV lane was not affected. The public outcry to such a high violation rate made transportation officials uncomfortable with the high violation rate.

Enforcement programs for arterial and downtown HOV projects are not only concerned with HOV violations but with other restrictions as well. These include turning and parking prohibitions that may be necessary to implement the HOV project. For several projects, these types of restrictions pose a greater potential hazard than an occupancy restriction. The primary objective of the enforcement effort associated with the Marquette/Second Avenues contraflow bus lane project in Minneapolis was not violations of the contraflow lane but rather motorist non-compliance with a "peak-hour, no stopping" ordinance necessary to maintain operational efficiency. Similarly, the enforcement needs for the N.W. 7th Avenue reversible lane project in Miami was primarily a left-turn restriction instituted along with the HOV project. This left-turn prohibition was instituted for safety reasons: left-turning vehicles create an accident potential by "cutting-off" express buses traveling in a center lane. A motorist making an illegal left turn may not realize that buses are traveling in a through movement in the left adjacent lane. Table 5 shows additional enforcement restrictions required by each of the HOV projects investigated.

For those projects that utilize a special or selective enforcement approach, it was found that little or no followup evaluation was conducted into the program's effectiveness. Such evaluations would have been beneficial, especially if it were determined that the same level of motorist compliance could be obtained by less enforcement effort. Only the Banfield Freeway and the U.S. 1/South Dixie HOV projects summarized the enforcement effort in terms of manpower allocations and citations issued that could then be correlated with the violation rate. For many of the projects the most widely-used performance measure for enforcement was the number or frequency of public complaints registered by telephone.

PRIORITY ASSIGNED TO THE HOV ENFORCEMENT EFFORT

The level of relative priority assigned by the enforcement agency to the HOV enforcement program is usually indicated by the type of enforcement program selected by deployment. Special enforcement

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9. The theoretical optimum occupancy rate is the theoretical number of people per vehicle that induces the highest possible level of passenger-moving performance on the facility. For further information regarding the optimal carpool occupancy, see Courage, K. B., et. al., "Traffic Control of Carpools and Buses on Priority Lanes on I-95 in Miami," University of Florida Transportation Research Center, FHWA Report No. FHWA-RD-77-148, August 1977.

indicates relatively high priority due to the additional resources required to execute such strategies. The extra enforcement personnel associated with a special enforcement program are assigned in order to detect, apprehend and cite the violators of the HOV restrictions.

Generally, when routine enforcement is utilized for HOV projects, the importance of HOV enforcement is of a lesser priority. For all projects except one, HOV enforcement is secondary to traffic enforcement activities involving traffic violations, which the enforcement agency perceives to be accident producing, such as speeding, reckless driving, following too closely and so forth. The Banfield Freeway HOV project in Portland was the only exception to this assignment of priority. For this project, the enforcement personnel on routine patrol were instructed to enforce HOV violations with the same intensity as other traffic violations. The fact that the Banfield Freeway project has a very intensive selective enforcement strategy could be a factor influencing the level of priority assigned to HOV enforcement during routine enforcement periods.

The Marquette/Second Avenues contraflow bus lane project in Minneapolis is enforced by "parking monitors" who concentrate on the "no-stopping or standing" restriction, which is the major enforcement requirement associated with the project. The parking monitors are not legally authorized to enforce traffic regulations other than parking violations, and no stopping or standing violations. Because of this fact, this project experiences an assignment of high priority to its enforcement needs.

Table 5 displays the relative priority assigned to enforcement on each HOV project included in this research.

ASSIGNMENT OF ENFORCEMENT PERSONNEL

As discussed in the previous section, the Marquette/Second Avenues contraflow bus lane project in Minneapolis utilizes parking monitors for HOV enforcement. The parking monitors are not sworn police personnel and as such cannot issue citations for moving traffic violations. However, as previously explained, these personnel lend themselves toward a relatively high level of priority for HOV enforcement. This project also receives benefit from another unique type of personnel: off-duty police officers. The off-duty officers are hired by major parking garages on Marquette Avenue to assist their customers in exiting the garage. A major reason for the need of this service is the safety implications of the contraflow bus lane located on the parking garages' side of the street. While performing their off-duty responsibilities, the off-duty officers also assist in the contraflow lane operation.

For the remaining HOV projects, the enforcement personnel consist of sworn police officers because of the obvious need to cite moving violations. Depending on the jurisdictional boundaries of the HOV project, the enforcement personnel could be affiliated with the state, county or municipal governments or any combination of the three.

Generally, special enforcement programs deployed daily on HOV projects are comprised of additional personnel acquired through hiring and/or overtime duty. These personnel are not withdrawn from other patrol duties. If the special enforcement program is part of a selective enforcement strategy, then the personnel are generally reassigned from other patrol duties for the period that special enforcement is applied.

The level of effort assigned to each HOV project is dependent on many factors, with the most significant ones being 1) project length, 2) project operation, 3) project restrictions, 4) enforcement strategy and 5) availability of enforcement personnel and funds. The number of enforcement personnel assigned to cover an HOV project can be highly variable between very similar projects. The I-95 HOV project in Miami has four to six highway patrolmen operating in a routine patrol mode over a project length of 7.5 miles (12.1 km), whereas a similar project, the Banfield Freeway HOV project in Portland has anywhere from two to eight troopers (two on regular patrol, six on special HOV patrol) over a project length of 1.7 to 3.3 miles (2.7 to 5.3 km). Partly because of this level of effort, the Banfield Freeway project enjoys a higher level of enforcement success than the I-95 project as measured by a violation rate of 20 to 25 percent for the Banfield against one of 50 to 70 percent for I-95. The I-95 and Banfield Freeway projects involve a concurrent-flow HOV lane in the median lane of a freeway with no inside shoulder existing for apprehension of violators. The violation rates presented are for a carpool occupancy restriction of three persons.[10] Table 6 displays the level of enforcement personnel assigned to each HOV project investigated through the course of this research.

ENFORCEMENT EQUIPMENT

Because HOV enforcement has followed traditional practices, the motor vehicle is the primary equipment item. The major difference in equipment used among the HOV projects was in the choice of motor vehicles. Most projects use either automobiles or motorcycles. Motorcycles provide enforcement with greater maneuverability but pose a much greater personal safety hazard for the operator, and are unuseable in bad weather. The general trend among traffic enforcement agencies is toward the elimination of the motorcycle. The parking monitors associated with the Marquette/Second Avenues contraflow bus lane project in Minneapolis use motorscooters in conjunction with their enforcement duties. Table 6 shows the type of vehicle utilized for each HOV project.

ENFORCEMENT BUDGET AND FUNDING

Generally, HOV enforcement programs are funded through the enforcement agency's existing budget. This is especially true for enforcement programs involving routine patrol and selective patrol strategies. Since most enforcement agencies believe they operate at undermanned and underfinanced levels, the competition for manpower and funds among the various police activities is intense. Almost uniformly, enforcement agencies place the priority of HOV enforcement somewhere less than the priority of public safety activities and traffic law enforcement activities involving hazardous driving. In such a context, it may be impossible for the enforcement agency to allocate special funds for special or selective enforcement of an HOV project, and thus the HOV project must operate with routine enforcement. Table 7 displays the methods of funding the HOV enforcement programs for each project investigated.

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10. For the highly publicized Santa Monica "Diamond Lane" project in Los Angeles which resembles the I-95 and Banfield Freeway projects (with the exception of an inside shoulder available for apprehension), the enforcement effort consisted of 20 to 22 troopers (6 to 10 on a regular patrol, 10 to 16 on special HOV patrol) over a project length of 12 miles (19.3 km). This assignment resulted in a violation rate of 10 to 20 percent. This project is not included in the research for this report.

TABLE 6

ENFORCEMENT PERSONNEL ASSIGNMENT/VEHICLE TYPE BY HOV PROJECT

	PROJECT	HOV CODE*	PERSONNEL ASSIGNMENT							VEHICLE TYPE		
			City Police	County Police	State Police	Routine Patrol Assignment (Vehicles)	Special Patrol Assignment (Vehicles)	Percentage Occurrence of Special Patrol	Project Length (Miles)	Sedan	Motorcycles	Motorscooter
FREEWAY	Shirley Highway - Washington, D.C.	1			x	3	1		12.0	x		
	Interstate 95 - Miami	2			x	4-6			7.5	x	x	
	Banfield Freeway - Portland	2			x	2	1-6	10	3.3	x		
	Route 101 - San Francisco	2			x	2-3	3-5	100	3.7	x	x	
	Route 101 - San Francisco	3			x	2-3			4.0	x	x	
	North Central Expressway - Dallas	4	x			0	1	3	1 ramp		x	
	Interstate 35W - Minneapolis	4			x	2-4	1-2	2	8 ramps	x		
	Santa Monica Freeway - Los Angeles	4			x	6-8	1-4		14 ramps	x	x	
	Interstate 5 - Seattle	5	x		x	1			1 ramp	x		
	San Francisco/Oakland Bay Bridge	6			x	5-6	3-4	5	1.5	x	x	
ARTERIAL	Nicollet Mall - Minneapolis	A	x			2			0.8			
	Elm/Commerce Streets - Dallas	B	x			2-3			0.7			
	Washington CBD - Washington, D.C.	B	x			1 for 36 square block	tow truck	100[a]	28.3	x		
	US 1/South Dixie - Miami	B	x	x			6-10	100	5.5	x	x	
	US 1/South Dixie - Miami	C	x	x			6-10	100	5.5	x	x	
	Marquette/Second Streets - Minneapolis	C	x			2-5			2.0			x
	Ponce de Leon/Fern. Juncos Aves.-San Juan	C	x			4-6			13.6	x	x	
	NW 7th Avenue - Miami	D	x	x		1	1	5	7.3	x	x	
	NW 7th Avenue - Miami	E	x	x		1			10.0	x	x	

*FREEWAY

1. Separate Roadway
2. Concurrent Lane
3. Contraflow Lane
4. Ramp Metering Bypass
5. Exclusive Ramp/Access
6. Toll Plaza Lane

*ARTERIAL

A. Separate Facility
B. Concurrent Lane
C. Contraflow Lane
D. Reversible Lane
E. Bus Pre-emption

a. On several streets only.

Metric Conversion

1 mile = 1.61 kilometers

TABLE 7

ENFORCEMENT FUNDING/PLANNING BY HOV PROJECT

	PROJECT	HOV CODE*	FUNDING			PLANNING		
			Within Existing Budget	Special Budget	Non-enforcement Sources	Early Involvement of Enforcement Agency	Grace Period	Examination of Innovative Techniques
FREEWAY	Shirley Highway - Washington, D.C.	1	x					
	Interstate 95 - Miami	2	x			x	x	x
	Banfield Freeway - Portland	2	x			x	x	
	Route 101 - San Francisco	2	x					
	Route 101 - San Francisco	3	x					
	North Central Expressway - Dallas	4	x					
	Interstate 35W - Minneapolis	4	x					
	Santa Monica Freeway - Los Angeles	4	x					
	Interstate 5 - Seattle	5	x					
	San Francisco/Oakland Bay Bridge	6	x			x		x
ARTERIAL	Nicollet Mall - Minneapolis	A	x			x		
	Elm/Commerce Streets - Dallas	B	x			x		
	Washington CBD - Washington, D.C.	B	x					
	US 1/South Dixie - Miami	B		x	x	x		
	US 1/South Dixie - Miami	C		x	x	x		
	Marquette/Second Streets - Minneapolis	C	x			x		
	Ponce de Leon/Fern. Juncos Aves.-San Juan	C	x				x	
	NW 7th Avenue - Miami	D	x				x	
	NW 7th Avenue - Miami	E	x					

*FREEWAY

1. Separate Roadway
2. Concurrent Lane
3. Contraflow Lane
4. Ramp Metering Bypass
5. Exclusive Ramp/Access
6. Toll Plaza Lane

*ARTERIAL

A. Separate Facility
B. Concurrent Lane
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D. Reversible Lane
E. Bus Pre-emption

Exclusive or preferential lanes for HOVs can be added to routes on the Federal-aid Primary, Urban and Secondary Systems Systems at the Federal participation level for those systems. The HOV lanes can be added to completed Interstate routes under certain conditions. Included for funding when HOV lanes are implemented on Federal-aid routes are the initial enforcement and personnel costs associated with implementing the HOV lane. Only Primary or Urban System funds can be used to provide 90 percent of these costs, regardless of the system.[11] None of the projects investigated utilized this funding source.

Only the U.S. 1/South Dixie HOV project in Miami with its special enforcement program has a special HOV enforcement budget. This special enforcement budget is funded by the sponsoring transportation agencies (Metropolitan Dade County and Florida Department of Transportation). For the first year of operation, when the project operated a contraflow bus lane and a concurrent-flow carpool lane simultaneously, special enforcement was budgeted at $63,638. This budgeted figure was exceeded by nearly $60,000 in the first year due to the need of maintaining a high level of enforcement throughout the project's operations.

As the U.S. 1/South Dixie project illustrates, HOV enforcement can be an expensive proposition. However, none of the enforcement agencies affected by an HOV project used this to justify special additional funding for its enforcement operations. However, HOV enforcement programs were considered in establishing some enforcement agencies' yearly overall budgets. Enforcement for the Banfield Freeway HOV project in Portland was calculated to be $20,659 per man-year. This figure includes personnel time, vehicle costs and overhead.

HOV enforcement should not necessarily be considered a drain on public funds. Each time a traffic citation is issued for an HOV violation, a fine is usually paid. The dollar amount of these fines is then allocated in some manner to the local and/or state government's treasury. It is possible for the dollar amount of fines collected for HOV citations to exceed the costs of enforcement for the HOV project. The special enforcement program for the U.S. 1/South Dixie HOV project in Miami issued 12,476 citations in the first year. At an established fine of $25, this number of citations would collect up to $311,900. This collection in fines compared very favorably to the $123,000 outlay for the special HOV enforcement program. However, this revenue was not returned to the agencies responsible for financing the enforcement operation but to the county's general treasury. The practice of not returning fines to the enforcement agency is a universal practice so as to avoid the implication of enforcement quotas in issuing citations.

ENFORCEMENT PLANNING

"The most significant factor in achieving a successful enforcement program appears to be early involvement in the planning process by representatives of the enforcement agencies affected."[12] This is especially true for HOV projects that will require either special or selective enforcement. The advantages of the early involvement of the enforcement agency in the planning process of an HOV project centers on the following areas:

11. U.S. Department of Transportation, Federal Highway Administration, (Office of Public Affairs), TSM . . . and Federal Aid Highway Funds for Transportation Improvements, 1977, p. 10-11.

12. Public Technology, Inc., A Manual for Planning and Implementing Priority Techniques for High Occupancy Vehicles, Technical Guide, prepared for U.S. Department of Transportation, Contract No. DOT-05-60076, July 1977, p. 77.

- provision of technical advice
- promotion of cooperative relationships
- personnel planning and budgeting

The police officer is a professional who is knowledgeable about motorist and pedestrian behavior. This knowledge is particularly useful to an HOV project when developing the enforcement program, safety program, and traffic operations plans as well as understanding judicial reaction to the project. By being involved in the planning process, the enforcement agency will more likely come to understand and accept decisions that may affect the enforcement effort, and develop a feeling of participation and self-importance. If the HOV project requires a special enforcement effort, it is especially valuable to involve the enforcement agency in this decision so that there is sufficient time for the agency to schedule the personnel and budget the required funds. The degree of enforcement agency involvement in the planning process varies between projects and is shown in Table 7.

The development of an enforcement plan containing a written set of enforcement procedures is advisable for even minor HOV projects for the following reasons:[13]

- field officers responsible for the day-to-day enforcement are often not the same officers who have been directly involved in the planning effort;
- a well-documented, comprehensive enforcement plan may assist in the defense of the project against legal challenges;[14]
- the enforcement plan lets other project operating personnel know what to expect from enforcement personnel; and
- the activity of developing the plan may in itself highlight previously unanticipated problems which can then be resolved by the project team before project installation. (The manual should also be revised as appropriate once operations have begun.)

Since the introduction of an HOV project involves an alteration of the physical facility and/or operating practice, motorists must become accustomed to new traffic patterns and restrictions. For many HOV projects, a grace period, generally of one to two weeks duration, was utilized to allow the motorists to become accustomed to the changes. It has also been a standard enforcement practice to pay greater attention, not necessarily in the form of the issuance of citations, to the initial weeks of the project's operation. This helps to facilitate the transition in traffic operations as well as maintaining a lower violation rate by providing visible enforcement. Table 7 illustrates which HOV projects employed a grace period.

The I-95 HOV project in Miami publicized a grace period at the commencement of the project which project management believed to be detrimental to the violation rate. It was theorized that many motorists knowing of the grace period, willfully violated the HOV lane. Since the threat of detection and apprehension never materialized for the HOV violation, these motorists were never effectively forced to

13. Ibid., p. 79-80.

14. A suit against the U.S. 1/South Dixie HOV project in Miami was dismissed largely because the enforcement manual, along with accompanying project documents showed to the judge's satisfaction that the County and State acted responsibly (Palladeno vs. Dade County; Case No. 74-20078, Circuit Court of the Eleventh Judicial Circuit of Florida).

stop using the HOV lane. This circumstance would seem to indicate that a grace period should incorporate at the least the issuance of warnings to provide a semblance of enforcement, and that the grace period should not be publicized. The practice of not employing a grace period could also be considered.

Because the HOV project design did introduce a new pattern of traffic violations and violators, several projects did review the possibilities of innovative enforcement techniques in the planning phase of the project.[15] Innovative techniques were investigated generally for those projects that had 1) the potential for a high violation rate and 2) geometric and operational features that made the standard enforcement techniques difficult to use. Table 7 shows those projects that seriously examined innovative enforcement techniques.

The major new technique explored was the utilization of a team concept to enforcement. In this technique, one patrolman would serve as the surveillance unit and detect the HOV violator; he would then transmit pertinent data on the violation (color of vehicle, license number, model, etc.) to a partner located further down the facility for apprehension purposes.

The specific technique examined on the I-95 HOV project in Miami included the use of cameras mounted on the patrol vehicle which would be used to photograph violators in the HOV lane. The identification of the vehicle would then be radioed to officers stationed at downstream exit ramps who would apprehend suspected violators, verify the occupancy and issue a citation. This technique was never implemented because of large manpower and cost requirements.

One approach which did prove to be easily implemented was the "shunt" lane technique used on the San Francisco-Oakland Bay Bridge toll plaza HOV lane. The shunt lane provides this project with a highly accessible refuge area and it is temporarily made by closing two traffic lanes immediately past the toll-booth plaza. This technique can generally be effective only in conditions where 1) excess capacity exists and 2) speeds are low, allowing for safe diversion of the violators.

HOV LEGAL/JUDICIAL ENVIRONMENT[16]

HOV projects present two basic legal issues: first, whether or not the particular agency has the authority to conduct an HOV project; and second, what risks of legal liability are faced by the agency when traffic accidents occur causing damages and injury. It is impossible to prepare an answer that is universally applicable to the HOV legal questions. The law in every state differs from that in any other state so far as the details of governmental authority and governmental liability are concerned. For this reason, any particular project should be reviewed by the proponents of the project as a part of the development of the specific proposal. Nevertheless, it is entirely feasible to make some generalized statement as to the procedure for approaching these issues and for the probable result if they are approached correctly.[17]

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15. For further discussion of innovative enforcement techniques, see Chapter 6, "Innovative Enforcement Techniques."

16. Chapter 7 presents a discussion on the legal issues associated with innovative enforcement techniques.

17. For a legal treatise on these issues, see Beiswenger, Hoch and Associates and University of Florida Transportation Research Center, Safety Evaluation of Priority Techniques for High Occupancy Vehicles, United States Department of Transportation, Federal Highway Administration, DOT-FH-11-9182, 1979.

In respect to the question of authority to conduct an HOV project, it can be stated without trepidation that the legislature in any state has the power to authorize such projects. As a general matter, it cannot be denied that these projects fall within the typical police powers of the state. It is quite another matter, however, as to whether a particular agency has been delegated the authority by the legislature to conduct such a project. Determining this would require examining the basic legislation establishing the agency in question and also, any specific legislation that may have been enacted to authorize an HOV project. If the implementing agency is a municipality, an affirmative answer to the question would be less likely than if the agency is a state authority such as a department of transportation. The amount of power inherent in municipalities to conduct innovative programs is generally restricted, but varies greatly from state to state, depending upon the amount of home rule authorized in the basic law of the state. Moreover, just as a state agency might be specifically authorized to carry out such a program, so also a municipality might be authorized by the legislature to do so. Hence, in making any meaningful statements about the authority question, one needs to know what state and what agency are to be involved.

The scope of tort liability is the second major legal issue to be addressed. Under the present state of the law, if there is to be liability imposed upon an agency in respect to an HOV project, it would be under that branch of the law known to lawyers as the law of negligence. A second aspect of the liability question involves an analysis of the doctrine of sovereign immunity. Traditionally, in this country, governmental agencies were not held accountable for negligent acts on the theory that the government was immune to suit. That theory has broken down to some extent in almost every state, and has been completely abrogated in some states.

Affecting the enforcement of an HOV project are the following:

- legal authority to conduct HOV projects
- litigation on HOV project authority and enforcement
- penalties for HOV citation
- judicial cooperation
- judgement decisions required by enforcement personnel

LEGAL AUTHORITY TO CONDUCT HOV PROJECTS

An HOV project can be the legal responsibility of the state, county or local government. The responsibility will rest with the entity that has primary jurisdiction over the transportation facility incorporating the HOV strategy. Generally, the enforcement agency of the governmental entity which has jurisdiction over the HOV facility will have the enforcement responsibility for the HOV project. There are, however, a number of exceptions to this generalization, mainly involving facilities under state jurisdictions where local agencies provide or share the enforcement responsibilities. Table 8 shows the legal authority and enforcement responsibility for each HOV project investigated.

The enabling legislation or ordinance that empowers the particular governmental entity to undertake the HOV project may be stated in 1) general terms, 2) special HOV language on a broad basis, or 3) special HOV language on a site-specific basis. The Ponce de Leon/Fernandez Juncos Avenues contraflow bus lanes in San Juan, Puerto Rico, are based on the existing authority of the Secretary of Transportation and Public Works for Puerto Rico to regulate traffic on state highways. The City of Dallas is more spe-

TABLE 8

RESPONSIBILITY/LEGAL AUTHORITY/PENALTY/JUDICIAL RELATIONSHIP BY HOV PROJECT

	PROJECT	HOV CODE*	RESPONSIBILITY		LEGAL AUTHORITY			PENALTY		JUDICIAL RELATIONSHIP		
			Legal Responsibility	Enforcement Responsibility	General Legislation	HOV General Legislation	Specific Project Legislation	Fine ($)	Point Assessment	Judicial Cooperation	Judicial Briefing	Enforcement Judgement
FREEWAY	Shirley Highway - Washington, D.C.	1	state	state		x		20	no	good		
	Interstate 95 - Miami	2	state	state	x			25	no	good	x	
	Banfield Freeway - Portland	2	state	state		x		17	no	good	x	
	Route 101 - San Francisco	2	state	state		x		19	yes	good		
	Route 101 - San Francisco	3	state	state		x		19	yes	good		
	North Central Expressway - Dallas	4	state/city	city		x		25	yes	good		
	Interstate 35W - Minneapolis	4	state	state	x			20	no	good		
	Santa Monica Freeway - Los Angeles	4	state	state		x		variable	yes	good		
	Interstate 5 - Seattle	5	state	state/city	x			18	yes	good		
	San Francisco/Oakland Bay Bridge	6	state	state		x		19	yes	good		
ARTERIAL	Nicollet Mall - Minneapolis	A	city	city			x	20	no	good		
	Elm/Commerce Streets - Dallas	B	city	city		x		20	yes	good		rt. turns
	Washington CBD - Washington, D.C.	B	district	district			x	25	no	good		rt. turns
	US 1/South Dixie - Miami	B	state	city/co.	x			25	no	good	x	
	US 1/South Dixie - Miami	C	state	city/co.	x			25	no	good	x	
	Marquette/Second Streets - Minneapolis	C	city	city			x	20	no	poor	x	
	Ponce de Leon/Fern. Juncos Aves.-San Juan	C	state	city	x			10	yes	good		
	NW 7th Avenue - Miami	D	state	city/co.	x			25	no	good	x	
	NW 7th Avenue - Miami	E	state	city/co.	x			25	no	good	x	

*FREEWAY

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4. Ramp Metering Bypass
5. Exclusive Ramp/Access
6. Toll Plaza Lane

*ARTERIAL

A. Separate Facility
B. Concurrent Lane
C. Contraflow Lane
D. Reversible Lane
E. Bus Pre-emption

cific in its enabling legislation by authorizing the Traffic Engineer to designate areas on public highways and streets for the exclusive use of buses. The City of Minneapolis is even more specific by passing an ordinance specifying the establishment of the Nicollet Mall transitway project. Table 8 shows the type of enabling legislation or ordinance associated with each HOV project.

LITIGATION ON HOV PROJECT AUTHORITY AND ENFORCEMENT

There have been relatively few challenges of the authority of the HOV projects or their enforceability. There have been challenges of individual tickets but the project personnel who were interviewed could provide no specific information on these.

However, there were two class action suits brought against the US1/South Dixie Highway project in Miami. These cases were Palladeno vs. Dade County and Weksler vs. Dade County. In Palladeno vs. Dade County, the plaintiffs claimed the contraflow bus operation to be hazardous and inadequately signed and protected. In Weksler vs. Dade County, several claims were made. The plaintiffs claimed to have a constitutional right (Fourteenth Amendment granting equal protection and the Fifth Amendment granting due process). They similarly claimed that the restricting of use of these lanes exceeded the police powers of Dade County. They claimed that the basic HOV priority concepts were discriminatory against persons in non-HOV's and claimed lost time and money due to their increased travel times.

Both suits sought to have injunctions brought to terminate the project. Both cases were dismissed on the grounds that the HOV regulations and restrictions which were implemented were within the police powers of Dade County. In the first case, the judge at first required that a task force be established to monitor the accident occurrences to see if the project was safe. This action was overruled as an infringement of the judicial branch of government over the legitimate functions of the legislative branch.

PENALTIES FOR HOV CITATIONS

The penalties associated with an HOV citation can be placed in the following two categories:[18]

- monetary fines
- "point" assessment on driving license

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18. On the I-93 carpool lane project in Boston, which is not included in the research for this report, travel time increases through route diversion have been used to penalize HOV violators. The system requires a single officer who simply directs violators away from the southbound regular traffic by diverting them to the northbound connector. If the violator is bound for downtown Boston or further south, it is estimated that this diversion increases the average travel time by 20 minutes. The travel time penalty is well received by both law enforcement personnel as well as motorists because 1) the penalty is appropriate for the violation, 2) traffic is not disrupted by the apprehension procedures, 3) enforcement efficiency can approach 100% of violators, 4) no special equipment or refuge area is required and 5) the officer's time is not consumed by court appearances. It is interesting to note that this tactic might be applicable to some curb bus lanes on arterial streets which permit right-turning vehicles in the lane. In downtown areas where one-way streets prevail, a single officer could institute a similar procedure by forcing auto traffic to turn right at a given intersection, provided no reasonable right turn opportunity is available immediately downstream of that location. For the projects investigated, no such strategy was applied to curb bus lane restrictions.

Generally, the HOV violation is cited either as a "failure to obey a traffic control device" if the project is based on general legislation or as a specific offense of the HOV designation if the legal statute/ordinance is more specific. The fine is dependent upon the fine schedule established within the jurisdiction responsible for the project, and ranges from $10 to $25 for the sites investigated. The average fine is $19.25.

Each state has a driver licensing point assessment program, whereby for certain moving traffic convictions, the driver receives an assessment of a point or points to his driving record. Temporary or permanent revocation of an individual's driving license occurs if the assessed point total exceeds an established limit within a certain period of time. One major indirect effect of a point assessment on one's driving record could be an increase in the automobile insurance premiums.

Point assessments associated with HOV violations are either non-existent or relatively small when compared to safety-related or accident-causing traffic offenses, which is the original basis for the point assessment program. The State of Florida has established a policy whereby the violation of the HOV lane restriction on any HOV project (I-95, US 1/South Dixie and NW 7th Avenue projects in Miami) would not receive a point assessment because of the non-hazardous nature of the offense.

Table 8 shows the penalties associated with an HOV violation for each project. For those HOV projects that have associated parking and turning restrictions, the penalties are standard as assessed by the jurisdiction's fine schedule.

JUDICIAL COOPERATION

A good enforcement program can be undermined by the judicial branch of government if the judicial branch does not uphold the citations issued by the enforcement agency. If a police officer continually finds his citations being overturned in traffic court, he is often inclined to issue fewer citations for the offense in question. Knowledgeable motorists may also become aware of certain traffic citations that are not being upheld by the traffic court system, particularly if publicized in the news media.

An HOV project is susceptible to misinterpretation by the judicial branch. The HOV project oftentimes incorporates a traffic scheme and traffic regulations that are unique to the area. Incomplete judicial understanding of the HOV project could result in judicial overrulings of the HOV citations. Additionally, because of the unique traffic scheme associated with HOV projects, traffic court judges can be more sympathetic to an alleged "confused and unsuspecting" motorist cited for an HOV violation.

Briefings for traffic court judges regarding the HOV project and its associated traffic regulations can be an important consideration influencing court attitudes. Judicial appreciation of the project's merits serves well toward developing the proper judicial support for the project. Specifically, the judges should be informed of 1) the objectives of the HOV project, 2) the traffic regulations applied to achieve the objectives, 3) the enforcement approach, 4) previous court rulings, if any, on similar projects, and

5) the legal basis for the restrictions and enforcement procedure. Table 8 identifies those HOV projects that project management found it appropriate to conduct a project briefing for traffic court judges.

All but one HOV project included in the research for this report found the judicial support of the project to be at least satisfactory.[19] There is, however, no readily available data that provides information on the number (or percentage) of HOV traffic citations upheld or overruled by the traffic court. The one exception is the Marquette/Second Avenues contraflow bus lanes project in Minneapolis where the traffic court has not fully supported the enforcement efforts. This uncooperative relationship between the two concerns did not develop with respect to the HOV project, but rather over the enforcement behavior of the meter monitors in general. The traffic court believed that the meter monitors had been overzealous in the enforcement of the "no stopping or standing" restrictions (at one time the meter monitors took down the license tag number of violating vehicles in order to mail citations) but this restriction, along with parking restrictions, are the main responsibilities of the meter monitors. Table 8 illustrates the degree of cooperation between enforcement and judicial concerns existing for each project.

JUDGEMENT DECISIONS REQUIRED BY ENFORCEMENT PERSONNEL

The traffic regulation establishing the vehicle and occupancy restrictions for an HOV project is concise and unambiguous in that either a motorist has, or has not, the required vehicle (bus) or the required number of occupants (carpool) to use the HOV lane. Certainly, there are problems associated with accurately identifying the number of occupants within the vehicle. Similarly, the traffic regulations involving left-turns and parking/no-stopping restrictions associated with an HOV lane are also unambiguous.

Curb bus lane projects that allow right-turning vehicles to use the bus lane do require judgement decisions by the enforcement personnel. The Elm/Commerce Streets concurrent flow curb bus lanes project in Dallas allows right-turning vehicles to use the bus lane for a "close as practicable" distance prior to making the right turn. The phrase "close as practicable" is not legally defined and is thus subject to interpretation by the motorist, enforcement personnel and judicial concerns. There is no well-accepted standard regarding "close as practicable" to aid the enforcement personnel in their duties. The Washington D.C. curb bus lanes more specifically defines the usage of the bus lane by right-turning vehicles, limiting the latter to traveling the bus lane only within one block of the right-turn. This can also be difficult for the enforcement personnel to enforce. Table 8 identifies the HOV projects requiring such judgement decisions by enforcement personnel.

HOV ENFORCEMENT PROBLEMS AND DEFICIENCIES

From the research conducted on the various HOV projects, transportation and enforcement

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19. A problem with judicial support occurred on the San Bernardino Freeway Exclusive Bus/Carpool Lanes Project. Motorists complained of ambiguities in the restricted lane signing and some traffic court judges agreed that the signing was unclear and accordingly dismissed a number of cases. While this project is not explicitly included in this research, some information on this project is provided in Chapter 4.

officials have identified a number of problems and deficiencies associated with their HOV project enforcement programs. These problems and deficiencies can be categorized in three areas: 1) geometric, 2) operational and 3) institutional. Recommendations to counter these problems and deficiencies are also presented.

GEOMETRIC-RELATED PROBLEMS AND DEFICIENCIES

The detection, apprehension and citation efficiency of an HOV enforcement program can be adversely affected by the absence of certain roadway features. These geometric deficiencies can also affect the safety and traffic operational features of the highway. These problems are more often associated with freeway treatments than arterial treatments, and with mobile patrol rather than stationary patrol enforcement tactics.

The primary problem has been the lack of a safe and easily accessible refuge area bordering the HOV lane which can be used to apprehend and cite HOV violators. This problem requires the enforcement officer, in order to access any refuge area, to 1) force the violator to cross the regular congested traffic lanes to the outside shoulder, or 2) follow the violator through the HOV system. The former method has negative safety and traffic operations implications, while the latter method could be very time consuming and inefficient. Some enforcement agencies have a standard policy of not crossing highly congested traffic lanes when executing apprehension maneuvers. This problem is most pronounced on freeway treatments where the inside lane is designated as the HOV lane, and there is no useable space between the HOV lane and barrier wall in the freeway median to serve as a refuge area for apprehension purposes. Both the I-95 HOV project in Miami and the Banfield Freeway HOV project in Portland have experienced this problem.

The absence of any vantage point by which enforcement can observe the HOV facility while keeping out of view may cause enforcement to be 1) inefficient, and 2) too visible. If an HOV project is lacking adequate observation areas, then detection of violators must often be conducted from a moving vehicle in, or adjacent to, the HOV lane. Under this detection procedure, the number of vehicles observed using the HOV lane is greatly limited when compared to stationary observation. If HOV enforcement is highly visible then HOV violators may be able to avoid detection. Enforcement procedures of various ramps on the Santa Monica Freeway bus/carpool bypass ramps project in Los Angeles are too highly visible to the motorists. Would-be HOV violators can easily see whether selective enforcement is taking place on that day, and if not, violate the HOV restrictions.

Some concurrent-flow HOV projects do not have the HOV lane physically separated by barriers, traffic posts or other implements from the general traffic lanes. Such a circumstance provides the motorist with an infinite number of locations to violate the HOV regulation and thereby places greater demands on the enforcement program. The greater the number of entry/exit points to the HOV lane, then the greater are the chances of HOV violations occurring. Without stipulated entry/exit points, violators are not committed to the HOV lane for a particular distance as would be under a physically separated system. HOV violations are often temporary or short-term in nature in order to circumvent heavily congested locations. On the I-95 HOV project in Miami, carpool flow rates are essentially constant throughout the HOV lane, whereas the violator flow rates are significantly larger in the high traffic

density sections.[20] By increasing the number of entry/exit points for an HOV lane, the risk of detection and apprehension is decreased while at the same time the opportunity for travel time benefits through congestion avoidance is increased—an unfavorable relationship for enforcement.

If an HOV facility does not have a paved surface, clear of obstructions, for passing, then apprehension maneuvers can be difficult since general traffic lanes, especially on freeways, are usually congested. In such circumstances, the enforcement vehicle may have to follow a violator for an extended distance when a legal HOV vehicle is positioned between the enforcement vehicle and the violator. Apprehension can take place only when 1) the vehicles travel all the way through the HOV system to uncongested areas, 2) the violator exits the HOV lane or 3) the legal vehicle exits the HOV lane. These type of apprehension maneuvers lessen the efficiency of the enforcement effort. Again, the I-95 and Banfield Freeway HOV projects suffer from the problem of no HOV passing zones or suitable areas for efficient pursuit operations.

Table 9 shows the geometric problems and deficiencies experienced by each HOV project.

OPERATIONAL-RELATED PROBLEMS AND DEFICIENCIES

On HOV systems where carpools are permitted, the determination of the number of occupants in a vehicle is made difficult by 1) young children, 2) vans, mobile homes, etc., 3) mirrored glass, 4) hours of darkness, and 5) inclement weather. It is generally believed that a two-person occupancy restriction is easier to determine than a three person or more occupancy restriction. It is not unusual for officers to detain a vehicle in an apparent violation of the vehicle occupancy restriction only to find one or more young children sitting lower than the window level.[21] Such occurrences, if frequent enough, would tend to discourage enforcement personnel while alienating the driving public. Several enforcement agencies generally follow the practice of terminating enforcement of vehicle occupancy restrictions during periods of darkness or inclement weather. Darkness is of special concern during the winter season, however, well-lighted highways can still provide sufficient background illumination to visually acquire silhouette images of occupancy.

Most HOV projects are designed to obtain a speed differential between the HOV lane and the general traffic lanes. This circumstance presents a significant safety concern for all traffic, but it may be especially hazardous for police officers during pursuit and apprehension of HOV violators. This problem is usually associated with mobile patrols and it is especially acute when 1) there is no refuge area next to the HOV lane and 2) the HOV lane and general lanes are not physically divided. The urgent need at times for officers to enter and exit the HOV lane and escort violators to the outside shoulder makes them vulnerable to this operational problem. In entering the HOV lane from the general travel lanes, the vehicle

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20. See Courage, K. G., et. al., op cit.

21. The Moanalua Freeway Carpool Lane in Honolulu, which is not included in the research for this report, originally had a vehicle occupancy restriction of four persons. On one occasion, a vehicle carrying three persons was reportedly apprehended for a carpool violation, however, the motorist claimed to have four persons in the vehicle since one female passenger was pregnant. The police officer unhesitatingly issued two tickets—one for a carpool violation and the other for having four persons riding in the front seat. When contested in traffic court, this case was dismissed, as the presiding judge did not believe his court was the appropriate one to argue legal points regarding the conception of human life.

TABLE 9

ENFORCEMENT PROBLEMS AND DEFICIENCIES BY HOV PROJECT

	PROJECT	HOV CODE*	GEOMETRIC				OPERATIONAL				INSTITUTIONAL				Total No. of Items
			Lack of Refuge Area	Lack of Vantage Point	Lack of Physical Separation	Lack of Passing Zone	Determination of Number of Occupants	Speed Differential Between HOV Lane and General Lanes	Lack of Visibility for Issuance of HOV Citation	Judgement Required by Enforcement	Lack of Cooperation	Traffic Enforcement Law Constraints	Manpower Limitations	Low Probability of Citing/Low Fine	
FREEWAY	Shirley Highway - Washington, D.C.	1					x								1
	Interstate 95 - Miami	2	x	x	x	x	x	x	x		x	x	x	x	11
	Banfield Freeway - Portland	2	x	x	x	x	x	x	x						7
	Route 101 - San Francisco	2			x	x	x	x	x			x			6
	Route 101 - San Francisco	3													0
	North Central Expressway - Dallas	4												x	1
	Interstate 35W - Minneapolis	4		x									x	x	3
	Santa Monica Freeway - Los Angeles	4	x	x				x					x	x	5
	Interstate 5 - Seattle	5	x				x		x				x		4
	San Francisco/Oakland Bay Bridge	6			x[a]										1
ARTERIAL	Nicollet Mall - Minneapolis	A												x	1
	Elm/Commerce Streets - Dallas	B	x		x	x			x	x				x	6
	Washington CBD - Washington, D.C.	B	x		x	x			x	x			x	x	7
	US 1/South Dixie - Miami	B			x	x	x	x							4
	US 1/South Dixie - Miami	C				x		x							2
	Marquette/Second Streets - Minneapolis	C	x								x	x	x		4
	Ponce de Leon/Fern. Juncos Aves.-San Juan	C	x		x			x	x				x	x	6
	NW 7th Avenue - Miami	D			x			x	x				x	x	5
	NW 7th Avenue - Miami	E													0

*FREEWAY

1. Separate Roadway
2. Concurrent Lane
3. Contraflow Lane
4. Ramp Metering Bypass
5. Exclusive Ramp/Access
6. Toll Plaza Lane

*ARTERIAL

A. Separate Facility
B. Concurrent Lane
C. Contraflow Lane
D. Reversible Lane
E. Bus Pre-emption

a. Actually the lanes are separated by safety posts near the toll booths, but the low speed enables easy penetration of this delineation.

will be traveling slower, at first, than the other vehicles in the HOV lane. Conversely, in exiting the HOV lane into the general travel lanes, the vehicle will be traveling, at first, faster than the other vehicles in the general travel lane. Safety problems develop when the vehicle in the former situation does not accurately gauge the speed of the vehicles in the HOV lane, or in the latter situation, minimal acceptable gaps for merging between vehicles in the general travel lanes do not exist.

For HOV projects where refuge areas are not adjacent to the HOV lane, the citing of HOV violators is less visible to the motorists. For instance, if the HOV lane is the left lane of the roadway and the apprehension area is on the right side of the roadway, then once the HOV violator is brought to the apprehension area, subsequent passing motorists cannot be certain for what traffic violation the citation is being issued. Some enforcement agencies have operating procedures, especially for freeway enforcement, requiring citations to be issued off the freeway and out-of-sight of the passing motorists. This is done to decrease the "shock-wave" effects on traffic flow associated with "rubber-necking" by passing motorists. In these instances, any value accrued from the visibility of the enforcement operation is lost. Many enforcement agencies believe that visibility of enforcement is as important, if not more so, that the issuance of the citation itself. In fact, analysis of data on the Banfield Freeway HOV project in Portland indicates that the HOV violation rate is more responsive to changes in the amount of enforcement manhours than to changes in the number of citations issued.

On the other hand, the visibility of enforcement on an HOV lane may result in HOV violators hurriedly exiting the HOV lane in order to avoid apprehension. This has serious safety implications, especially when traffic in the general lanes is congested and a significant speed differential between the HOV lane and general lanes exists.[22]

Certain HOV restrictions require judgement decisions on the part of the enforcement personnel. The primary judgement situation faced by enforcement personnel focuses on curb bus lanes and the use of the bus lane by right-turning vehicles. The judgement decision is "at what point can a right-turning vehicle enter the lane?" These decisions are especially difficult for the Elm/Commerce Streets concurrent flow bus lanes in Dallas since the right turning vehicles are allowed to use the bus lane within "as close as practicable" distance to the right turn location. A similar situation exists on the Washington D.C. curb bus lanes, but the more specific guideline of "within the block preceding the right turn" makes the judgement less difficult.

Table 9 shows the operational problems and deficiencies experienced by each HOV project.

INSTITUTIONAL-RELATED PROBLEMS AND DEFICIENCIES

A good enforcement program for an HOV project requires proper coordination and cooperation

22. Safety research on the Santa Monica "Diamond Lane" project in Los Angeles supports the hypothesis that enforcement may have accounted for some portion of the higher accident rate on that facility through lane-changing and increased congestion from "rubber-necking." Because of this possibility, enforcement officials decided not to detain violators on the inside shoulder area, but instead on the outside shoulder. See: Billheimer, John W., Santa Monica Freeway Diamond Lanes: Freeway Accident Analysis; paper presented at the 57th Annual meeting of the Transportation Research Board, January 1978, pages 15-21.

between project management, enforcement and judicial interests. If the cooperation between any two participants deteriorates, for whatever reason, then the enforcement program will suffer. A lack of sufficient interaction between project management and enforcement interests in the planning of an HOV project could leave enforcement officials unconvinced of the viability of the HOV project and thus place HOV enforcement operations in a very low priority category. The primary objective of traffic law enforcement is to protect lives and property by enforcing hazardous moving violations. The promotion of public welfare through alleviation of traffic congestion or expediting traffic flow is usually a secondary objective. With the introduction of an HOV project, enforcement personnel may be asked to reevaluate their traditional role by placing additional emphasis on the passenger flow objective. Enforcement officials do not always concur with this change of emphasis. Similarly, traffic court judges may not have a full understanding of the HOV project and its special traffic regulations, or they may feel that the enforcement personnel are overzealous. As a result, judges could become over-lenient toward violators, which in turn, could have a tendency to discourage aggressive enforcement of HOV restrictions. On the N.W. 7th Avenue reversible lane project in Miami, some citations for left-turn violations were dismissed by traffic judges, who failed to comprehend why left-turns had to be prohibited. After a briefing of traffic judges, this misunderstanding was resolved.

Traffic law may limit the effectiveness of potential HOV enforcement programs. Because of geometric or operational problems associated with an HOV project, it may be extremely difficult for the "witnessing" officer to be the "apprehending" officer. In such circumstances, enforcement may be better handled through a "team approach" whereby one officer identifies the violator and a second officer apprehends the violator. This enforcement strategy is not possible if the appropriate traffic law stipulates that the officer witnessing a violation must also be the apprehending officer. On the Marquette/Second Avenues contraflow bus lanes project in Minneapolis an enforcement manpower constraint required "meter monitors" to be responsible for enforcement of a "no stopping or standing" ordinance associated with the HOV project. Since the meter monitor's legal authority precludes any pursuit tactics, it is quite common for violators to avoid apprehension by simply leaving prior to the meter monitor's arrival. This legal constraint imposed upon the meter monitors hinders the effectiveness of the HOV enforcement program.

Manpower constraints face many enforcement agencies regardless of the traffic enforcement requirements imposed on the agency. The primary need for HOV enforcement occurs during the peak traffic periods. This is the time of day that normally places the greatest demand on traffic enforcement personnel anyway. In certain instances, the traffic enforcement agency does not have surplus manpower to allocate to HOV enforcement. Some HOV restrictions may be 24-hour restrictions requiring enforcement to occur throughout the day, even at times (off-peak hours) when the HOV project is not providing any real benefits to its users. Twenty-four hour enforcement may increase the manpower needs of the enforcement agency unnecessarily.[23]

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23. On the San Bernardino Freeway concurrent-flow, but separated, HOV lanes in Los Angeles, which is not included in this research, buses can use the HOV lanes 24 hours a day, while carpools can only use them during peak periods. The absence of any positive traffic control guidance leads some carpoolers to use the lanes during off-peak hours. This is particularly true after major sports events in the area when congestion increases and priority treatment would be justified for carpools.

A low probability of being cited, especially when combined with a low fine, offers little incentive toward compliance with HOV restrictions. The perceived benefit from violating the HOV project may outweigh the perceived risks associated with this violation. For the Ponce de Leon/Fernandez Juncos Avenues contraflow bus lanes project in San Juan, Puerto Rico, encroachment into the HOV lane by illegally parked vehicles is a major problem. The vehicles park illegally in these locations because 1) off-street parking rates are very expensive, 2) few parking tickets are issued and 3) the parking fine is not much more, if at all, than the parking rates. For violators, it may be financially advantageous to violate the law under these circumstances.

Table 9 summarizes the institutional problems and deficiencies experienced by each HOV project.

RECOMMENDATIONS FOR PROBLEMS AND DEFICIENCIES

It has been previously discussed that the most significant factor in achieving a successful enforcement program appears to be the early involvement in the planning process by representatives of the enforcement agencies affected. The advantages to early involvement of the enforcement agency in the planning process of an HOV project centers on the following areas:

- provision of technical advice
- promotion of cooperative relationships
- personnel planning and budgeting

The fostering of a productive relationship between HOV project management and the enforcement agency can address itself to, and help solve, a number of problems, including:

- the need for geometric enforcement features (such as accessible refuge area, vantage point, etc.)
- enforcement of HOV system placed on low priority
- incompatibility between various legal restrictions and the planned enforcement approach
- requirement of judgement decisions on the part of enforcement personnel concerning whether or not a certain movement is a violation

Similarly, by bringing the judicial branch into the planning phase, crucial judicial support for the HOV project can be obtained. A briefing document has been successfully used to acquaint the traffic judges with HOV projects. It is important that judges develop an appreciation for the objectives of the HOV project and the enforcement approach needed to achieve the objectives.

The geometric feature that has the greatest impact on HOV enforcement is the existence of an easily accessible refuge area. Such a refuge area can improve the detection, apprehension and citation efficiencies of the HOV project. The existence of the refuge area could provide these benefits:

- minimize the manpower required for apprehension and surveillance
- maximize the visibility of the enforcement effort and serve as a deterrent
- improve the safety of the pursuit and apprehension functions

Manpower constraints can limit or preclude HOV project enforcement operations even under the most compatible geometric conditions and the most amicable interagency relationships. Without additional funds, specifically earmarked for HOV enforcement, an enforcement agency may feel that it cannot justify the re-allocation of certain peak hour safety-related patrols. Therefore, this conflict has only two potential solutions—1) specially allocated HOV enforcement funding or 2) substantially improved techniques/technologies for executing the HOV enforcement function that will minimize manpower requirements.[24]

Changes in traffic enforcement law[25] would address those HOV legal problems associated with enforcement. One statutory change which holds promise is the decriminalization of HOV violations. This could allow for the mailing of the citation to the registered owner of the vehicle, in much the same way he would be cited for a parking ticket. It then would be the responsibility of the owner to prove that he was not operating the vehicle at the time the violation occurred. The mailing of citations could drastically reduce the manpower requirements of the enforcement effort. The problem of determining the number of occupants in a vehicle might be eased by statutory changes that place the burden of proof of occupancy on the owner or operator of the vehicle. Such a legal provision would be necessary to utilize an enforcement technique that involved photographic instrumentation and the mailing of citations.

HOV ENFORCEMENT PROGRAM PERFORMANCE

In this section, the enforcement programs, which are used on the HOV projects, are examined as to their relative effectiveness, efficiency and influences on overall project operations. The HOV enforcement related data (violations, traffic volumes, citations, violators observed, etc.) is often incomplete or non-existent on many HOV projects. In the absence of data, the research has developed approximations based on detailed discussions with the HOV transportation and enforcement personnel. HOV enforcement program performance is examined by 1) the violation rate, 2) the detection/apprehension/citation efficiency and 3) the effect on traffic operations and safety. The individual projects are discussed in greater detail in Chapters 4 and 5.

VIOLATION RATE

The primary measure of all effectiveness of an HOV enforcement program is the violation rate achieved. On most projects, and for the purposes of this report, the violation rate is defined as the percent of the total number of vehicles using the HOV lane which fail to meet eligibility criteria for the HOV lane.[26] The violation rates for the HOV projects encompass a wide range of percentages—from a nearly zero percent violation rate to a violation rate of over 50 percent, the latter percent meaning that

24. For further discussion of innovative enforcement techniques, see Chapter 6, "Innovative Enforcement Techniques."

25. For further discussion of the legal issues associated with HOV enforcement, see Chapter 7, "Legal Issues Regarding HOV Enforcement."

26. The issue of what constitutes a good measure of effectiveness with respect to violations is currently a subject of debate. The authors acknowledge inherent deficiencies in the measure used, but point out that data was generally unavailable to allow the use of any better measure.

the majority of vehicles using the HOV lane are violators. Similar projects with similar geometry and operating strategies can have drastically different violation rates because of the type and level of enforcement employed. A case in point is the I-95 HOV project in Miami and Banfield Freeway HOV project in Portland. The Banfield Freeway project is experiencing a 20 to 25 percent violation rate under extensive selective enforcement and the I-95 project is experiencing 50 to 70 percent violation rate using routine enforcement. The violation rates for both of these concurrent-flow freeway HOV projects are based on an HOV occupancy requirement of three persons. These numbers verify the obvious phenomenon that selective enforcement will lessen the violation rate. The U.S. 1/South Dixie HOV project in Miami has a well-financed special enforcement program (using Dade County Public Safety Department officers) that achieves a violation rate of 2 to 7 percent, thus showing the even greater capabilities of a special enforcement program in achieving a low violation rate.

The fact that an HOV project is experiencing a relatively high violation rate may not necessarily indicate failure of the HOV project objectives. The intent of employing a certain type of enforcement strategy is, in part, to achieve a violation rate that is agreed upon as tolerable to project management, enforcement personnel, motorists, or the general public. A high violation rate could very well be considered to be tolerable by the determinant group. The issue of "what is an acceptable violation rate?" has previously been discussed on page 20 . A high violation rate may be considered an acceptable violation rate if it does not compromise the objectives of the HOV project. If a routine patrol enforcement strategy is not capable of achieving an acceptable violation rate, then selective patrol and special patrol strategies should be considered.

For some HOV projects on arterial streets and downtown streets, the violation of driving illegally in the HOV lane is not the main concern of the HOV enforcement program. This issue also has been previously discussed on page 22 . Because of safety and traffic flow considerations, certain restrictions as to left-turns and parking comprise the major emphasis of enforcement. The N.W. 7th Avenue reversible lane project in Miami and Marquette/Second Avenues contraflow bus lanes project in Minneapolis had few vehicles illegally traveling in the HOV lane, but did experience a large number of left-turn and parking violations respectively. Violation rates for these type of restrictions were not available on any project investigated.

Table 10 shows the violation rate, relative acceptability of the violation rate and other HOV-related restrictions for each HOV project.

FACTORS AFFECTING THE VIOLATION RATE

There are a number of factors that affect the violation rate. These include: 1) HOV lane signing, 2) bus vs. carpool HOV lane restriction, 3) travel time benefits, 4) probability of apprehension, 5) accessibility to the HOV lane, 6) operating period, 7) occupancy restriction, 8) visibility, and 9) weather conditions. More visible and frequent HOV lane signing increases the likelihood that motorists traveling the facility will understand and abide by the HOV restrictions. A violator would tend to violate more readily under a bus/carpool HOV lane restriction than a "bus-only" restriction since the violator would be more conspicuous under the "bus-only" restriction. Violators tend to violate in order to gain travel time benefits, therefore, as the travel time benefit improves, the incentive to violate increases. Conversely, as the probability of apprehension improves, the incentive to violate decreases.

TABLE 10

ENFORCEMENT PERFORMANCE/BENEFIT-RISK/TRAFFIC DISRUPTION BY HOV PROJECT

	PROJECT	HOV CODE*	PERFORMANCE			BENEFIT-RISK				TRAFFIC DISRUPTION		
			Violation Rate (%) of HOV Lane	Acceptability of Violation Rate	Additional Enforcement Restrictions (Table 4)	Peak Hour Travel Time Advantage of HOV Lane (Min.)	Apprehension Rate (%)	Fine for HOV Violation ($)	Violator Cost of Travel Time ($/hour)[c]	Detection	Apprehension	Citation
FREEWAY	Shirley Highway - Washington, D.C.	1	3	yes		8.5	2	20	3	x		x
	Interstate 95 - Miami	2	62[a]	no		3.5	1	25	41		x	x
	Banfield Freeway - Portland	2	20-25	yes		1.4	10.7	17	80		x	
	Route 101 - San Francisco	2	15	yes		1.5	8	19	61		x	x
	Route 101 - San Francisco	3	0	yes		2.0	100	19	570			
	North Central Expressway - Dallas	4	40	yes		1.5	2	25	20			
	Interstate 35W - Minneapolis	4	2[b]	yes		.4-6.0	1	20	2-30		x	
	Santa Monica Freeway - Los Angeles	4	6-60	no		1-6	NA	19	NA			x
	Interstate 5 - Seattle	5	4	yes		NA	NA	18	NA			
	San Francisco/Oakland Bay Bridge	6	7	yes		5.0	2.9	19	7		x	x
ARTERIAL	Nicollet Mall - Minneapolis	A	0-1	yes	x	minus	0	20	—			
	Elm/Commerce Streets - Dallas	B	14	yes	x	minus	0	25	—			x
	Washington CBD - Washington, D.C.	B	NA	no	x	minus	NA	25	NA			x
	US 1/South Dixie - Miami	B	5-12	yes	x	7.4	10.6	25	21			
	US 1/South Dixie - Miami	C	0-1	yes	x	10.6	NA	25	NA			
	Marquette/Second Streets - Minneapolis	C	0-1	yes	x	minus	NA	20	NA			x
	Ponce de Leon/Fern. Juncos Aves.-San Juan	C	0-1	yes	x	NA	NA	10	NA			x
	NW 7th Avenue - Miami	D	NA	yes	x	2.3	8	25	52			x
	NW 7th Avenue - Miami	E	0	yes		4.7	NA	25	NA			

*FREEWAY
1. Separate Roadway
2. Concurrent Lane
3. Contraflow Lane
4. Ramp Metering Bypass
5. Exclusive Ramp/Access
6. Toll Plaza Lane

*ARTERIAL
A. Separate Facility
B. Concurrent Lane
C. Contraflow Lane
D. Reversible Lane
E. Bus Pre-emption

a. This is under a carpool restriction of three persons; it has since become a two person restriction having a violation rate of 33%.

b. This is for bus-only ramps; bus/carpool ramp has a violation rate of 20%.

c. Cost of Travel Time = $\frac{\text{actual cost}}{\text{actual benefit}} = \frac{\text{apprehension rate} \times \text{fine (\$)}}{\text{travel time savings (hr.)}}$

The more frequent the entry/exit locations to the HOV lane, then a greater capability exists for violators to engage in "congestion avoidance"—i.e., using the HOV lane in only those locations where traffic congestion is occurring in the general travel lanes. A 24-hour HOV operating strategy permits the installation of permanent traffic control devices (signs, pavement markings and delineators) thereby improving the motorists' familiarization with the HOV lane. A peak-period HOV operating strategy generally has its highest violation rate in the first and last half-hour of the HOV operation. A lower occupancy restriction causes a lower percentage of total vehicles to be classified as "non-eligible" vehicles for travel in the HOV lane. During periods of darkness or reduced light conditions, which HOV operations may experience, auto occupancy may be difficult to determine. During rainy or foggy weather conditions, auto occupancy may be difficult to determine or enforcement personnel may be reluctant to issue traffic citations.

There are two types of violators—willful and non-deliberate. The latter category of violator is often unfamiliar with the facility, may be confused easily or just does not look for traffic signs. Some people driving by habit may unknowingly violate the HOV facility. In some limited cases HOV projects could be better signed to minimize the occurrence of the non-deliberate violations.

When a motorist willfully violates the HOV lane, he presumably believes that he has a very good chance of escaping apprehension. In short, the motorist's perceived benefits outweigh the perceived risks associated with the violation.

The overwhelming benefit that a motorist would receive is the travel time savings in the free-flowing HOV lane as opposed to the congested general lanes. The travel time benefit also holds true for a left-turn violation associated with an HOV project. The travel time benefit to be received varies according to the length of HOV lane violation and the corresponding speed differential between the HOV lane and general lanes. With more than one entry/exit points, the HOV lane violation need not consume the entire length of the HOV lane. Oftentimes, as discussed on this page, the HOV violation will be one of congestion avoidance—the violation occurs in those sections of the facility where congestion is located. The travel time savings associated with the complete length of the HOV project during the peak travel period is highly variable among the HOV projects because of the fluctuations in traffic flow and differences in operating strategies and lengths of the projects.

The travel time savings, or perceived benefits, is but one side of the issue. If the probability of being apprehended for the HOV violation is 100 percent, then the violation rate would approach zero regardless of the magnitude of the travel time savings. This is the advantage of the HOV projects that have a single entry/exit point allowing one enforcement officer to monitor the vehicles using the facility. As the perceived probability of apprehension decreases, the potential of HOV violations occurring increases. The perceived probability of apprehension is also dependent on the visibility of the enforcement operation. The apprehension of the HOV violators may be great, but if it is not in view of the motorists, then the perceived probability of apprehension could be much lower.

The probability of being apprehended and cited for an HOV violation is dependent upon 1) the number of enforcement personnel assigned to HOV enforcement, 2) the time consumed by detection, apprehension and citation procedures, and 3) the number of HOV violators. These factors to some degree are interrelated. If the time consumed by the detection, apprehension and citation procedures is particularly long, then additional manpower may be necessary to achieve the enforcement objective. The detection, apprehension and citation procedures can vary among projects according to the geometrics

and operating strategy as discussed later on this page. The greater the number of violators traveling in the HOV lane, then the less conspicuous a single HOV violation becomes, and the smaller the probability of conventional apprehension.

Complementing the apprehension probability is the penalty associated with an HOV violation. The perceived risk to a motorist is the combination of probability of apprehension and the size of the penalty. The greater the penalty, then the greater is the perceived risk. Conversely, if the penalty is low, then the perceived risk is lower. The Ponce de Leon/Fernandez Juncos Avenues contraflow bus lane project in San Juan, Puerto Rico, experienced a parking violation problem because the penalty and the probability of being cited was very low.

The ratio of risk to benefit yields a potential cost to the HOV violator of travel time savings received. Risk can be calculated by multiplying the apprehension rate by the fine and would be measured in dollars. Benefit would be the travel time savings as measured in units of time. The ratio would then yield a potential cost for the violator measured as dollars per hour or minutes saved. The violator cost of travel time saved varies widely among the HOV projects. The I-95 project has a very low value ($4/hour saved), which favors violations, due to a low apprehension rate (1 percent) and a relatively high travel time savings per trip (3.5 minutes). On the other hand, the Banfield Freeway project has a much higher value ($80/hour) due to a higher apprehension rate (10.7 percent) and a lower travel time savings (1.4 minutes in the AM peak hour).

There is no discernable relationship between the violation rate and the violator cost of travel figures. An ideal relationship would be one where the violation rate decreased as the violator cost of travel time increases. The U.S. 1/South Dixie project has a violation rate of 5 percent associated with a cost of $21/hour saved, whereas the Banfield Freeway project has a violation rate of 20 percent associated with a cost of $80/hour. This lack of a relationship would seem to indicate that the perceived values of benefit and risk could be far different than the actual values. Not all motorists will violate the HOV lane under the same conditions because their perception of the benefits and risks may vary widely.

This analysis as to why or why not motorists violate the HOV lane is simplistic in that there are many other factors involved in one's choice in selecting to violate the HOV lane restriction. The other prominent reasons are the difficulty of entering and exiting the lane, other safety considerations and the convenience of the lane. There are many motorists who very much abide by the established traffic regulations and would not violate the HOV lane under any circumstances (excepting an extreme emergency).

Table 10 shows the maximum travel time advantage, apprehension rate, fine for HOV violation, and the violator cost of travel time for each HOV project investigated.

DETECTION/APPREHENSION/CITATION EFFICIENCY

The overall effectiveness of any enforcement effort must be partially related to the time consumed by the detection, apprehension and citation procedures. For example, if a single officer required fifteen minutes to detect, apprehend and cite an HOV violator (four per hour) on a facility where the violator flow rate exceeded 100 vehicles per hour, then violators could reasonably perceive a lowly four

percent chance of being cited.[27] The perceived enforcement efficiency would be even lower if the apprehended violators are removed from the roadway or away from the priority lanes. In order to raise the probability of the HOV violator being cited, additional enforcement personnel would be necessary.

Certain roadway geometrics and operating strategies affect detection, apprehension and citation efficiency. These efficiencies are improved if the roadway and HOV operation contains the following features:

- safe and easily accessible refuge area(s) bordering the HOV lane in which to cite HOV violators
- existence of a vantage point(s) by which enforcement personnel can observe the HOV lane while keeping, for the most part, out of view from the motorists
- physical barrier between the HOV lane and the general traffic lanes
- existence of a passing zone or area allowing enforcement vehicles to pass other vehicles in the HOV lane

The I-95 HOV project in Miami experiences low efficiency in its detection, apprehension and citation procedures. Detection is difficult because of a lack of a vantage point thereby requiring the enforcement personnel to patrol the HOV lane by traveling in the adjacent general lane. Apprehension is difficult because there is no easily accessible refuge area and available passing area. This forces the apprehension procedure to occur by 1) following the violator to the end of the HOV lane, or 2) crossing three to four general lanes of heavily congested traffic in order to reach a refuge area (outside shoulder). With violator flow rates in the HOV lane exceeding at times 500 vehicles per hour, the most concerted routine enforcement efforts would be unable to apprehend a significant percentage of violators because of the detection and apprehension inefficiencies.

The U.S. 1/South Dixie HOV project in Miami operates with efficient detection, apprehension and citation procedures. Enforcement personnel are stationed in the left-turn storage bays which are blocked off during the project's operation. Upon detection of an HOV violator, the officer steps to the edge of the lane and signals the car into the left-turn storage area serving as a refuge area. Because the sight distance into the median area is poor, enforcement of the HOV lane is not apparent until the vehicle is upon the area—too late for a violator to undertake evasive maneuvers, but highly visible to the other passing motorist. These favorable enforcement efficiencies coupled with a special enforcement program combine for a relatively low violation rate (5 to 12 percent) on the project.

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27. It should be noted that if a facility were experiencing a high percentage of repeat violators, even a low apprehension percentage could have a cumulative positive effect on habitual violator behavior through daily occurrence of enforcement. In the example cited, if all 100 violators were habitual (daily) violators, then over an extended period of time with the lowly apprehension rate of 4 percent, enforcement will eventually reach the majority of violators. (Applying probability statistics to this example, it would take 18 days of this level of enforcement to reach a majority (51) of the violators. Additionally, over 25 days of enforcement and 100 citations issued, the probability is that 64 percent of the violators would receive one or more citations.) The possibility exists, however, that police officers may initially perceive a seemingly insurmountable task from this low apprehension rate with the resultant effect of "why try?"

The fact that one project may have more favorable detection apprehension and citation procedures than another project, does not necessarily mean that more citations per enforcement manhour will be issued on the former project than the latter project. A good case in point is a comparison of the Banfield Freeway HOV project in Portland and U.S. 1/South Dixie HOV project. While the U.S. 1/South Dixie project has more efficient detection, apprehension and citation procedures, the Banfield Freeway project has the higher number of citations issued per enforcement manhour—1.4 citations per manhour on Banfield Freeway compared to a range of .7 to 1.6 citations per manhour on U.S. 1/South Dixie. This statistic is also dependent upon 1) the responsibilities of the enforcement personnel, 2) the enforcement strategy, 3) the use of warning methods in lieu of issuing citations and 4) the volume of violators. It is important to realize that "citation efficiency" is not necessarily a good index for measuring enforcement program performance, since a highly efficient enforcement program can drastically reduce the number of violations, thereby reducing the opportunity to issue citations.

HOV ENFORCEMENT EFFECT ON TRAFFIC OPERATIONS AND SAFETY

Generally, one of the objectives of HOV projects is to improve traffic flow on the particular facility. However, enforcement of the HOV projects oftentimes disrupts traffic flow. The degree to which enforcement can disrupt the traffic operations is primarily a function of the project geometry and the enforcement procedure. Traffic flow problems may be directly or indirectly related to HOV enforcement.

The directly-related traffic flow problems are mainly associated with an apprehension procedure resulting in hazardous weaving maneuvers performed by the enforcement vehicle alone or the enforcement/violator tandem. This problem is made more serious by the lack of an easily accessible refuge area, which creates difficult weaving maneuvers; by the existence of a speed differential between the HOV lane and general lanes which makes weaving more difficult; and by traffic density or gap distribution which also makes weaving more difficult. Several HOV projects have experienced accidents involving the enforcement vehicle. If there are no refuge areas available to the project, then the citation must be issued somewhere on the street, either in the HOV lane or the general traffic lanes. This procedure can seriously disrupt traffic flow and is most often associated with downtown projects.

Once an HOV violator is escorted to a refuge area, the enforcement effort can be indirectly involved in disrupting traffic flow and contributing to traffic accidents through the pehnomenon known as "rubber-necking," which is associated with the curiosity of motorists and the presence of enforcement of any kind. The traffic flow disruption in the vicinity of an enforcement operation often remain long after the violator and enforcement personnel have left the scene and substantial hazards are created for rear-end collisions on freeway facilities.[28] Because of this circumstance, some enforcement agencies prefer to detain motorists away from the mainstream of traffic. However, as previously noted, this procedure may require even more of the police officer's time and decreases efficiency and visibility benefits of the enforcement operation.

Table 10 shows which HOV projects experience traffic flow disruptions as a result of its detection, apprehension and citation procedures.

28. Safety research on the Santa Monica "Diamond Lane" project in Los Angeles supports the hypothesis that enforcement may have accounted for some portion of the higher accident rate on that facility. See: Billehimer, John W., Santa Monica Freeway Diamond Lanes: Freeway Accident Analysis; paper presented at the 57th Annual meeting of the Transportation Research Board, January 1978, pgs. 15-21.

CHAPTER FOUR

ENFORCEMENT OF HOV PRIORITY TREATMENT PROJECTS ON FREEWAYS

GENERAL

Enforcement needs, techniques, and problems differ greatly between freeways and arterial highways. Freeways have a limited access operation, much larger volumes of traffic, higher speeds and more frequent incident occurrences, which have a substantial effect on traffic flow. In some respects, enforcement is simpler on freeways because officers can monitor a larger sample of traffic per unit of time. However, in other respects, enforcement of freeways is more difficult because of higher speeds, weaving maneuvers and the unavailability of detention areas (in many cases).

There are several enforcement factors common to freeway treatments and they are summarized as follows:

(1) Freeway enforcement is generally accomplished using line patrols, and is generally under the jurisdiction of the state highway patrol (or equivalent).

(2) During peak periods, freeway enforcement is generally oriented more toward incident management than enforcement. This is because traffic congestion is greater in the peak periods, producing an increase in accidents and erratic maneuvers and a decrease in speeds. The imposition of HOV restrictions requires a greater emphasis on traffic law enforcement.

(3) Some HOV treatments can introduce enforcement problems which are not related to violations of HOV restrictions. For example, if the addition of an HOV lane eliminates a median shoulder, off-peak breakdowns which seek refuge in the HOV lane can lead to accidents, which naturally require the attention of the enforcement agency.

Freeway Standards

Current national standards on geometric design for freeways are established by AASHTO.[1] These design policies do not specifically address HOV priority treatment projects, however, the general geometric design standards apply equally to HOV facilities. Table 11 contains the design standards for pertinent geometric elements.

Current national standards on traffic control devices for freeway facilities are established by FHWA's Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD). The MUTCD has established special pavement markings and signing for preferential lane use control.[2] The pavement marking is

1. American Association of State Highway and Transportation Officials (AASHTO), A Policy on Geometric Design of Urban Highways and Arterial Streets (1973 edition), published by AASHTO, Washington, D.C.

2. United States Department of Transportation (Federal Highway Administration), Manual on Uniform Traffic Control Devices—Official Rulings on Requests, Volume VI, June 1975, pp. 7-8 and 41-42.

   Federal Highway Administration, "Changes in the Manual on Uniform Traffic Control Devices to Provide Pavement Marking and Signs for Preferential Lane Use Control," FHWA Notice N 5160.8, March 17, 1975.

an elongated "diamond" symbol formed by white lines. The frequency of the diamond marking is a matter of engineering judgement, but the MUTCD suggests a "spacing as close as 1000 feet (300 m) may be appropriate for a freeway." The signing regulations include 1) sign shape, color and reflectorization, 2) legend format and sequence, and 3) mounting applications. The type of preferential lane signs include lane-use control signs, advance notification signs, and lane end signs. The MUTCD suggests that the diamond marking symbol "should be incorporated into the body of the signs as a white symbol on a black background. The sign size, location and spacing are dependent upon the conditions under which it is used, but should be consistently applied." Table 11 and Figure 1 present the MUTCD standard for each traffic control element established for preferential lane control.

Recommendations

There are certain recommendations on enforcement of HOV priority treatment projects which are common to all freeway applications. These recommendations are:

(1) Enforcement requirements should be included in project planning in the earliest stages, and enforcement personnel should be active members of the planning team. The advantages of the early involvement of the enforcement agency in the planning process of an HOV project centers on a) provision of technical advice, b) promotion of cooperative relationships, and c) personnel planning and budgeting. Additional personnel and funds should be made part of the overall project plan if necessary. In order to minimize institutional misunderstandings (particularly after implementation), all decisions and agreements should be written and made official by formal memoranda of understanding or similar instruments.

(2) To the maximum extent possible, HOV priority projects should be designed, constructed and/or modified in strict conformance to AASHTO and MUTCD standards, as well as other appropriate site specific requirements.

(3) Officials of the traffic court system should be briefed, prior to the project start-up, regarding the project's operational goals, traffic restrictions, enforcement program and legal basis. Judicial appreciation of the project's merits serves well toward developing the proper judicial support for the project. Failure to gain this support may be reflected in judges being too lenient with HOV citations and thereby discourage enforcement efforts.

(4) On projects having travel time savings as its operational goal, the HOV restrictions should be imposed only during those time periods when these savings can be achieved. Otherwise, enforcement activity would be required when the project operation is not providing any benefit.

(5) The entire project should be opened at one time (at least by direction). Temporary and/or partial openings often create both safety and enforcement problems which may be greater than those associated with the full system.

(6) Priority sections should be particularly well maintained. The unusual conditions make it imperative to keep the roadway and traffic control devices highly visible. Where the median shoulder must be eliminated, lighting should be kept at high levels and reflectorized delineators should be installed on the face of median barrier walls so they are highly visible at night. The HOV lane should also receive supplemental "No Stopping This Lane" signs.

(7) Enforcement should be supported by extensive public education and publicity of the seriousness of the HOV restrictions. Enforcement agencies commonly agree that a public awareness program, which notifies the public of enforcement activities, increases the effectiveness of

TABLE 11

NATIONAL STANDARDS APPLICABLE TO HOV PRIORITY TREATMENT PROJECTS ON FREEWAYS

AASHTO DESIGN STANDARDS

1. Lane Width: 12 feet
2. Ramp Width: 25 feet for linear ramps, variable for curved
3. Shoulder Widths:
   a. Right: Desired 12 feet; minimum of 10 feet (or 8 feet if low truck volume)
   b. Left: 4 to 6 feet minimum for four lanes; 10 feet for six or more lanes
4. Type Shoulder: Paved, flush
5. Medians with Barrier:
   a. Type: Clearance with safety profile or double "W" corrigated steel
   b. Clearance: 6 feet minimum for four lanes; 10 feet minimum for six or more lanes
6. Roadside Hazards: 20 feet minimum to edge of right-of-way, 6 to 10 feet to obstacles

MUTCD DESIGN STANDARDS

1. Signalization: Lane-use controls on reversible lanes and access ramps
2. Signing:

	Roadside	Overhead
a. Advanced Warning:	R3-10	R3-13
b. Restricted Lane:	R3-11	R3-14
c. End of HOVL:	R3-12	R3-15

3. Lane Demarcation: Solid or skipped white line[a]
4. Special Markings: Diamond symbol, spaced frequently enough to be in constant view
5. Delineators: Plastic posts (reversible and contraflow lanes only)

Metric Conversion:

1 foot = 0.3 m.

a. There is some question concerning the use of solid lines. While the MUTCD is not explicit, solid lines should be used on HOV lane projects which are either bus-only or 24-hour operations.

FIGURE 1

MUTCD RECOMMENDED PREFERENTIAL LANE-USE CONTROL SIGNS

ADVANCE WARNING:

R3-10

(roadside)

R3-13

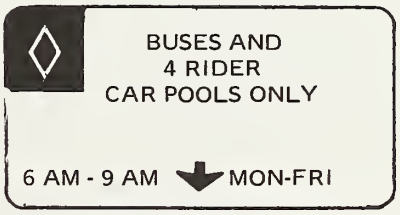
(overhead)

RESTRICTED LANE:

R3-11

(roadside)

R3-14



(overhead)

END OF HOVL:

R3-12

(roadside)

R3-15

(overhead)

the enforcement effort. The public awareness program should be a continuing, on-going program.

(8) Aggressive enforcement should begin immediately to instill a degree of respect of the HOV restrictions. However, the tactics used should initially be "soft" and should minimize traffic disruption. For example, very heavy deployment of troopers in a highly visible fashion would create a respectful enforcement impression. The use of "wave-off," verbal warning (e.g. use of loud speakers), and other non-punitive techniques is preferred to the sudden disruptive effect of massive apprehensions. Publicity of this initial enforcement period should state that enforcement of the HOV restrictions is beginning immediately. The transition to the issuance of citations should be made in no more than two weeks and preferably one, depending on the anticipated disruption which will occur. Following an initial "crackdown," the aggressiveness and deployment can probably be relaxed.

(9) A readily accessible refuge area (full shoulders) should be provided for stationary observation and apprehension. If this is not possible, serious consideration should be given to extensive selective, special or instrumented enforcement tactics. Chapter 6 presents more details concerning possible innovative instrumented techniques and their legal ramifications are discussed in Chapter 7.

The remaining sections of this chapter contain detailed information on enforcement requirements and problems regarding the five major types of HOV priority treatments on freeways:[3]

1. separate facilities
2. concurrent flow lanes
3. contraflow lanes
4. ramp metering bypass operations
5. toll plaza strategies

Representative projects of each treatment were investigated in detail as part of this research. The results of these investigations constitute the major emphasis in the discussions; however, insights from other projects are included to augment and qualify the findings on the projects investigated.

SEPARATE FACILITIES

Separate freeway facilities for HOVs include separate roadways and exclusive ramps. These facilities are designated for exclusive use by specified HOVs and all other vehicles are expressly prohibited. The separation can be either permanent or partial.

The separate roadway can lie within the median of the freeway or it can be entirely removed from the freeway. Completely separated roadways are really independent highways with no interaction with the general lanes, except at the terminal points. Thus, they should have all the geometric attributes of separate highways including full lane widths, shoulders and appropriate lane striping (if more than one lane). If they are aligned adjacently to the general-use highway, they should be separated by barrier walls and should have full shoulders on both sides. This configuration obviously requires a wide right-of-way.

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3. For a complete evaluation of safety problems associated with HOV priority treatments, see Beiswenger, Hoch and Associates and Transportation Research Center, Safety Evaluation of Priority Techniques for High Occupancy Vehicles, Federal Highway Administration, DOT-FH-11-9182, 1979.

Partially separated lanes can have shared shoulders which reduces right-of-way requirements. In this design, the restricted lanes are accessible from the general lanes and this increases the likelihood of violations. This joint-use shoulder can be penetrated by both violators and HOV vehicles. Indeed, crossing the shoulder-separator by any vehicle is a violation in itself which further compounds the enforcement requirement.

Exclusive ramps are generally composed of two types. One type connects general-use lanes with HOV-specific facilities, such as bus terminals, in order to allow direct access to or from these restricted areas. This type is not a priority treatment per se, but it operates similarly. There is little propensity for violators to intentionally use such ramps. The second type is the "typical" HOV priority facility which is intended to give preferential service to HOVs. There is a higher probability of violations on these ramps, since they also serve desirable origin-destination patterns of low occupant vehicles.

Because separate facilities are generally separated physically and have limited (discrete) access/egress, they possess many of the operational characteristics of "tunnel" facilities, one of which is an irrevocable commitment to using the facility. This attribute makes separate facilities generally easy to enforce. If separation is not total, this enforcement benefit is diminished accordingly.

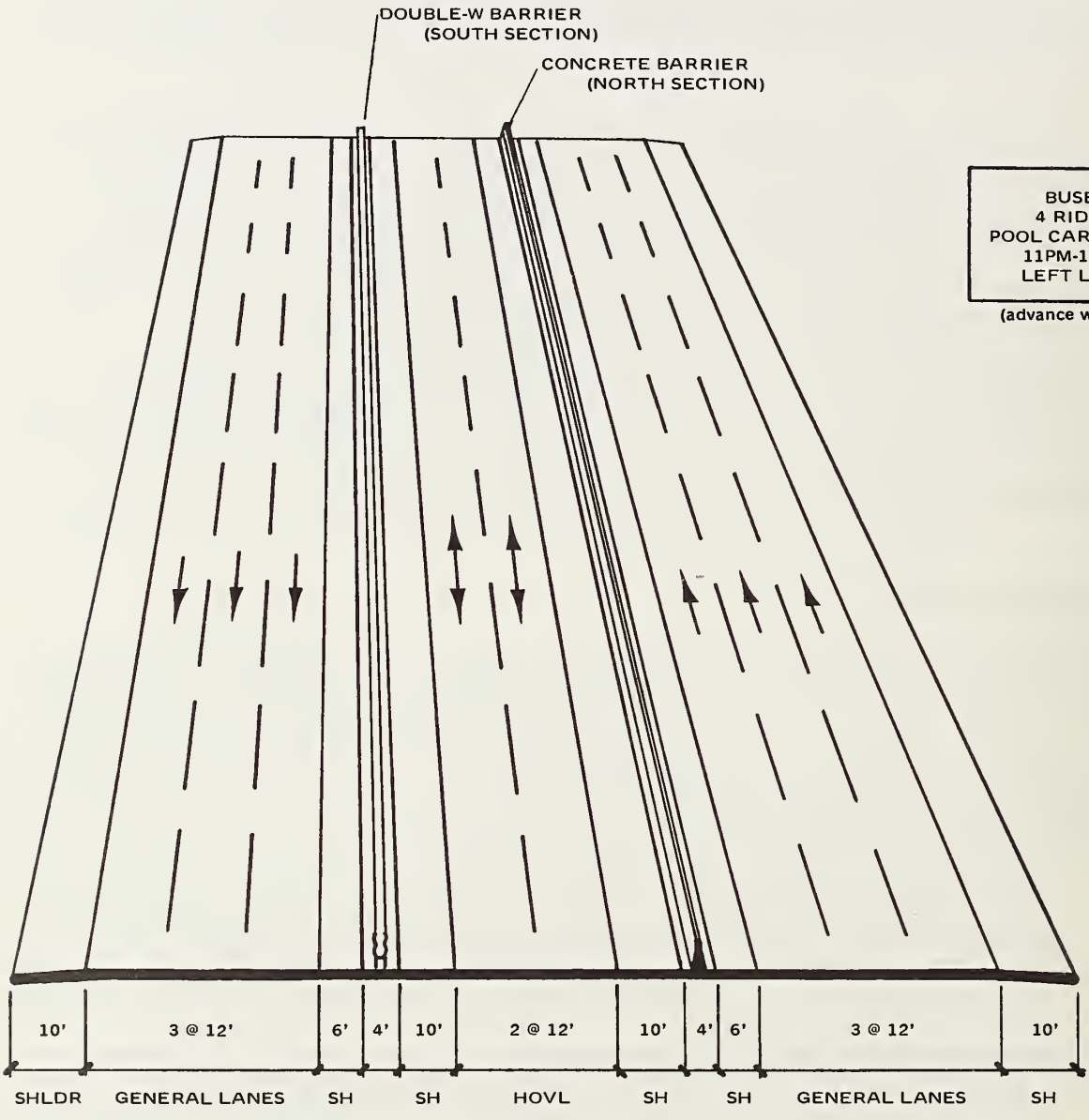
Details of Projects Investigated

By and large, enforcement of separate roadways for HOVs is relatively easy. For this reason only the Shirley Highway reversible HOV lanes on I-95/395 in northern Virginia and Washington, D.C., was investigated in detail. However, because the partially separated lane project on the San Bernardino Freeway in Los Angeles has dissimilar enforcement problems, significant details of this project are also included in this section. Project descriptions are given below and in Figures 2 and 3.

- Shirley Highway, Fairfax County, Virginia (Figure 2)
  Major reconstruction of the Shirley Highway in the late 1960's and early 1970's produced an eight-lane facility, with three general lanes in each direction and two reversible lanes in the median. The reversible lanes are reserved for buses and carpools of four or more persons per vehicle (ppv). The reversible facility operates inbound (NB) from 11 PM to 11 AM and outbound (SB) from 1 to 11 PM. In the outbound mode, general traffic is allowed to cross through the median barrier into the reversible lanes prior to a major interchange downstream in order to reduce demand in the two general lanes. Thus, the HOV treatment operates for only about six miles (9.7 km) outbound compared to 11.5 miles (18.5 km) inbound. Bus-only operations began on the partially completed facility in September, 1969, and carpools were admitted to the completed facility in September, 1973.

- San Bernardino Freeway, Los Angeles, California (Figure 3)
  This was an eight-lane urban freeway when a portion of a railroad right-of-way in the median was taken and a lane was added in each direction for exclusive use by buses. This mode of HOV operation began in January, 1973, and the lanes were restricted 24 hours a day. In October, 1976, carpools of at least 3 ppv were allowed to use the lanes inbound (WB) from 6-10 AM and outbound (EB) from 3-7 PM, Monday through Friday (but this has since been changed to include all days). Buses still use both lanes at all times. As shown in Figure 3, the HOV lanes are separated from the general lanes by a common shoulder. Although the shoulder is fully striped and has vertical tubular posts, vehicles may violate by crossing through the safety area. This system is seven miles (11.3 km) long in both directions.

FIGURE 2
SHIRLEY HIGHWAY, FAIRFAX COUNTY, VIRGINIA



METRIC CONVERSION
1 in = 2.54 cm
1 ft = 0.3 m
1 mi = 1.61 km

AASHTO DESIGN FACTORS

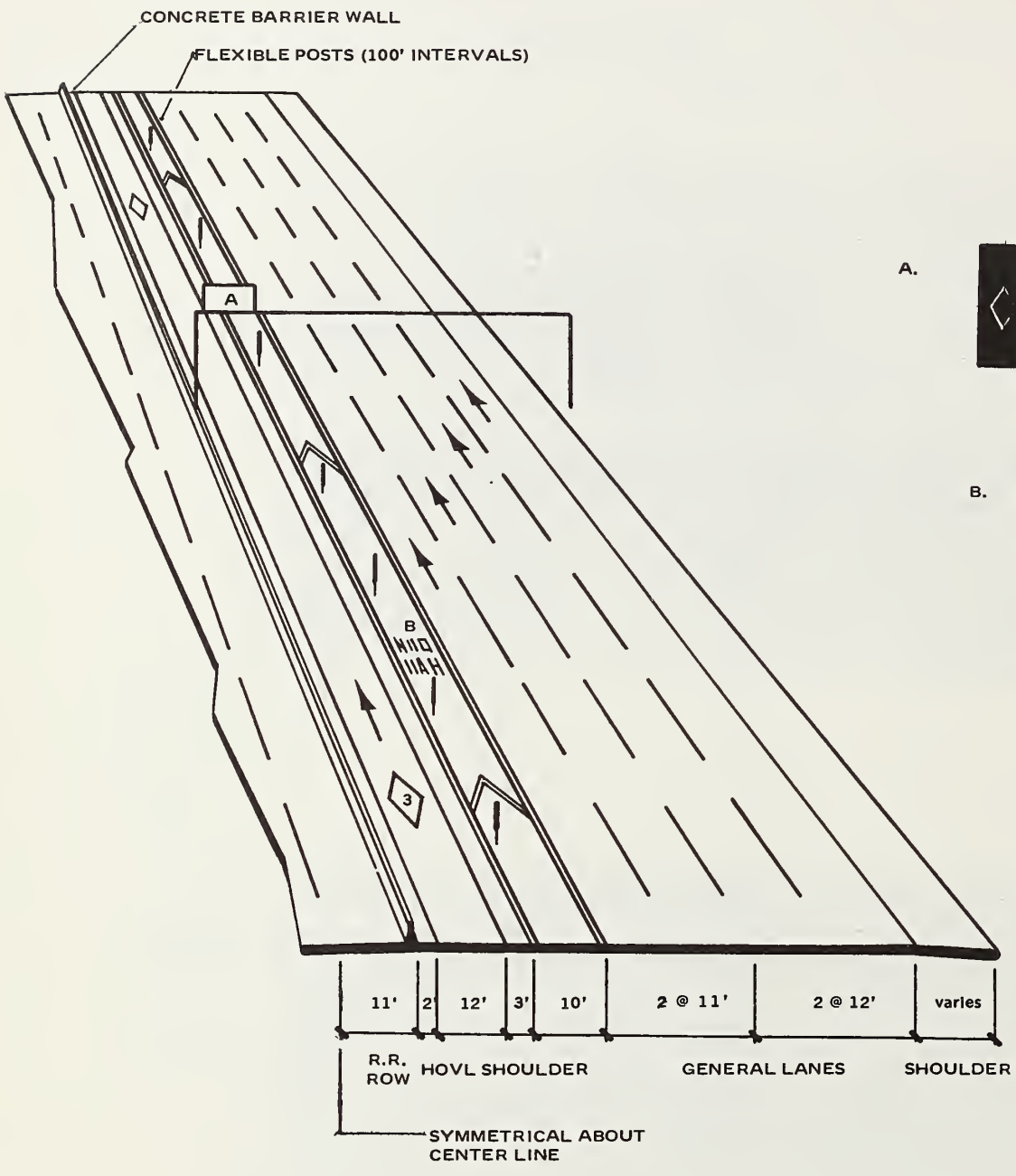
ALIGNMENT: linear
VERTICAL SIGHT DISTANCE: good
POSTED SPEED: 55 mph
ROADSIDE HAZARDS: none
OTHER HAZARDS: crossover for general traffic southbound

MUTCD DESIGN FACTORS

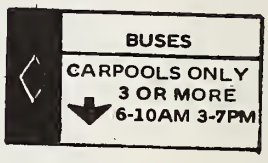
LANE-USE CONTROL SIGNALS: none
ADVANCED WARNING SIGNS: non-standard
RESTRICTED LANE SIGNS: none
END OF HOVL SIGNS: none
DIAMOND SYMBOL: none
HOVL DELINEATION: barrier walls

SHIRLEY HIGHWAY, FAIRFAX COUNTY, VIRGINIA

FIGURE 3
SAN BERNARDINO FREEWAY (CONCURRENT SECTION), LOS ANGELES, CALIFORNIA



A.



B. PAVEMENT MARKING:
"EMERGENCY STOPPING ONLY"

METRIC CONVERSION
1 in = 2.54 cm
1 ft = 0.3 m
1 m = 1.61 km

AASHTO DESIGN FACTORS

ALIGNMENT: linear
VERTICAL SIGHT DISTANCE: good
POSTED SPEED: 55 mph
ROADSIDE HAZARDS: walled sections

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: none
ADVANCED WARNING SIGNS: standard
RESTRICTED LANE SIGNS: standard
END OF HOVL SIGNS: standard
DIAMOND SYMBOL: standard (500' intervals)
HOVL DELINEATION: shared shoulder with double yellow lines, safety posts and other marking

SAN BERNARDINO FREEWAY (CONCURRENT SECTION), LOS ANGELES, CALIFORNIA

Table 11 presents the national standards applicable to HOV priority treatments on freeways.

On the Shirley Highway project, there are no deficiencies in the geometric design either on the mainline or the connecting ramps. There are ten connecting ramps, which are either reversible or one-way, and one slip ramp through the median wall. Traffic control is basically restricted to the access/egress points since the HOV facility is otherwise inaccessible. No signalization is used in conjunction with access control, but rather signs indicate the periods during which the ramps are available for access in each direction. Manually operated gates are used to block the ramps to oncoming traffic during periods when the opposing direction of travel is in operation. This is a technical violation of the MUTCD which specifies lane-use signals, but the barricades are a far more positive type of control since they physically block the closed ramp. All signing is non-standard and there are no mainline restricted lane-use signs. A typical warning sign reads, "BUSES—4 RIDER POOL CARS ONLY—(operating times)," and has an arrow directed at the ramp. The diamond symbol is not used. The project predates the standards and signing has not been upgraded, but there appears to be relatively little problem with motorists misunderstanding the restrictions.

Enforcement personnel for the Shirley Highway project have expressed a desire for mainline lane-use control signs be placed periodically within the reversible lane section, perhaps at one-mile intervals. The reason for this is that many apprehended violators claim they did not see the restricted access signs or that they were "pulled" in by the traffic stream and didn't realize they were violating any traffic laws. Periodic lane-use control signs may reduce these excuses and improve the enforcement process.

On the San Bernardino Freeway project, the only geometric design deficiency is the existence of limited shoulder widths in a few areas. All traffic control devices generally conform well to the standards except for the technical violation of using solid yellow edge lines on the median shoulder. This marking should be white indicating concurrent traffic and that crossing is permissible in an emergency. Lane-use control signs are posted at one-mile intervals, which is perhaps less than would normally be required for separated HOV lanes; however, the separate HOV lanes on the San Bernardino Freeway are accessible along the mainline by illegally crossing the common shoulder.

Operational Results

As discussed in Chapter 3, the extent of the enforcement requirement for an HOV project is dependent, in part, on the operational effectiveness of the project. The operational results of each project are displayed in Table 12. Only one peak period is presented—that which experienced the most serious enforcement problem, or for the period for which there were the most data. From Table 12, several of the more significant results are:

- Travel speeds in the separate facility HOV lane(s) are greatly superior to the travel speeds in the general lanes. For the Shirley Highway, the speed is 51 mph (82 kph) in the HOV lane compared to 30 mph (48 kph) in the general lanes. For the San Bernardino Freeway, the speed in the HOV lane is 57 mph (91 kph) compared to 39 mph (62 kph) in the general lanes.
- Because of these higher travel speeds, persons traveling in the HOV lane experience travel time savings over general lane travel. For the Shirley Highway, the average travel time savings is 9.3 minutes over the 11.5 miles (18.5 km). For the San Bernardino Freeway, the travel time savings is 3.4 minutes over the 7.0 miles (11.3 km).

TABLE 12

OPERATING CHARACTERISTICS ON SEPARATED HOV ROADWAY PROJECTS

VARIABLE	UNIT	PROJECT/CONDITION			
		Shirley Highway[a]	San Bernardino Freeway		
		Bus/4 ppv Carpool	Before[b]	Bus-Only	Bus/3 ppv Carpool
Critical Peak Period	—	6:30 - 9 AM	3 - 7 PM	3 - 7 PM	3 - 7 PM
Length of HOV Lane	Miles	11.5	—	7.0	7.0
Total Peak Directional Lanes	Lanes	5	4	5	5
Number of HOV Lanes	Lanes	2	—	1	1
Volume - All Lanes	Vehicles	18,400	28,018	28,018	28,346
Volume - HOV Lanes	Vehicles	1,948	—	168	906
Volume - HOV Lanes (bus only)	Vehicles	400	—	168	164
HOV Lanes/Total Volume	%	10.6	—	0.6	3.2
Auto Occupancy - All Lanes	PPV	1.57	1.30	1.25	1.28
Auto Occupancy - HOV Lanes	PPV	4.46	—	—	3.09
Person Throughput - All Lanes	Persons	46,388	40,096	40,096	41,543
Person Throughput - HOV Lanes	Persons	24,902	—	5,240	7,780
HOV Lanes/Total Throughput	%	53.7	—	13.1	18.7
Speed - General Lanes	MPH	30.2	35.0	37.0	39.0
Speed - HOV Lanes	MPH	51.0	—	57.1	57.1
Travel Time - General Lanes	Minutes	22.8	12.0	11.4	10.8
Travel Time - HOV Lanes	Minutes	13.5	—	7.4	7.4
Accident Rate	Acc./mvm	2.0	1.0	1.4	1.3

Metric Conversion

1 mile = 1.61 kilometers

a. No before data available.

b. No explicit before data were available; however, published reports and graphs indicate there was little change in volume or person trips between the before and bus-only stages, so the latter data are assumed to apply to both.

TABLE 13

ENFORCEMENT CHARACTERISTICS ON SEPARATED HOV ROADWAY PROJECTS

VARIABLE	PROJECT/CONDITION				
	Shirley Highway	San Bernardino Freeway			
	Bus/4 ppv Carpool	Bus Only		Bus/3 ppv Carpool	
	AM Peak Period	AM	PM	AM	PM
HOV Lane Volume	1,948	170	168	876	906
Number of Violators	48	0	0	44	82
Violation Rate (%)	2.5	0	0	5.0	9.1
Number of Citations	1.0	NA	NA	NA	NA
Apprehension Rate (%)	2.1	NA	NA	NA	NA

- The HOV lanes on both projects illustrate the efficiency of the operation. For the Shirley Highway, the HOV lanes carry 54 percent of the persons in 11 percent of the vehicles. The volume in the peak period (6:30 to 9:00 AM) is 1,948 vehicles of which 400 are buses. For the San Bernardino Freeway, the HOV lane carries 19 percent of the persons in 3 percent of the vehicles. The volume in the peak period (3:00 to 7:00 PM) is 906 vehicles of which 164 are buses.

Enforcement Characteristics

Chapter 3 presented details on HOV projects related to 1) the enforcement program, 2) enforcement problems and deficiencies, and 3) the performance of the enforcement program. These enforcement elements are summarized here for the two separate facility HOV projects.

- Shirley Highway, Fairfax County, Virginia
  Although the Virginia Department of State Police (VDSP) places a relatively high priority on enforcement of the HOV lanes, the relative ease of enforcement and low violation rate results in little special effort required. Routine line patrols monitor the normal operation using an average of three sedans, and occasionally another unit is assigned to selectively enforce the reversible HOV facility. The type of enforcement is generally a moving patrol and in the case of the selective enforcement the officer positions himself on the shoulder of the reversible roadway. Since violators cannot take evasive action, virtually all violators can be detected. Pursuit and apprehension is generally completed within the reversible roadway.

- San Bernardino Freeway, Los Angeles, California
  The fact that the common shoulder separating these HOV lanes from the general lanes can be crossed presents more enforcement problems on this project than on the Shirley Highway. Both low and high occupancy vehicles can violate by crossing the shoulder, so the problem is not restricted to the low occupant violator. Furthermore, detection of these violations is extremely difficult since the violations must be spotted when they occur, although vehicles with less than three occupants who enter the lane can be detected downstream. About six units (sedans) normally operate in the project area. This does not represent an increase in enforcement as a result of the HOV project but the California Highway Patrol (CHP) does place a high priority on HOV enforcement. Line patrols either travel in the left general lane or position themselves on the dividing shoulder. When violators are detected, they are generally pursued and stopped on the dividing shoulder.

The available violation data are presented in Table 13. From this table, several of the more significant results are:

- The differences in the operations of these two facilities produced differing violation rates. On the Shirley Highway, where no evasive action is possible, only 2.5 percent of the HOV lane traffic are violators. But on the San Bernardino Freeway where controls are less positive, the AM and PM violation rates were 5 percent and 9.1 percent respectively during bus/carpool operations. It should be noted that the violator flow rates (vph) were similar on both projects (about 20 vph). There were virtually no violators during bus-only operations on the San Bernardino Freeway.

- On the Shirley Highway project, only about 2 percent of all violators are apprehended. While this number may seem low, the daily number of violations is also small. There is no similar data available for the San Bernardino Freeway project.

On other separate facility projects, the violation rates were similarly low. For example, the western section of the San Bernardino Freeway has a separated busway. There have only been a few violations in the several year history of its operation. Beginning in June 1977, carpools (3 ppv) were also permitted to use this busway and preliminary reports indicate that the violation rate is only 5 to 6 percent. On the I-5 exclusive bus/carpool ramp in Seattle, the violation rate is also about 5 percent.

In summary, separate HOV roadways characteristically have low violation rates, varying from 0 to 6 percent where separation is permanent and from 5 to 10 percent where violators can gain access/egress by crossing partial separations.

Geometric Standards Related to Enforcement

Enforcement of completely separated roadways is normally accomplished by stationary monitoring of the HOV lanes from the adjacent shoulders. When offenders are detected, they are either waved over or pursued and pulled over to the shoulder. Pursuit is far more efficient on facilities with more than one HOV lane because other HOVs between the officer and violator can be passed more easily. On single-lane facilities, such as the San Bernardino Freeway, passing requires a hazardous maneuver by sedans, thus, motorcycles are better suited. Stopping violators on shoulders presents a potential safety hazard to both officer and violator as well as the passing traffic.

All these enforcement requirements suggest that shoulder design on separated HOV facilities at least meet, but preferably exceed AASHTO standards. The same recommendation applies generally to exclusive ramps.

On the San Bernardino Freeway, one problem did arise at the input terminal in the outbound direction (EB). On the approach to the separated HOV lane facility, the old left shoulder has been repaved and designated as an unseparated concurrent HOV lane leading to the separated facility via a ramp. This one-mile long section is within a major interchange which experiences congestion at times. Violators use the HOV lane to bypass most of the congestion and then merge back into the general ramp lane. If congestion is severe, the merge is often delayed and the violator is either "forced" to remain in the HOV ramp accessing the mainline separated HOV facility or the violator may stop in the approach lane which can lead to accidents. A similar, but less severe, problem from the safety standpoint exists on the inbound approach to the I-5 exclusive bus/carpool ramp in Seattle.

Such access lane problems suggest that inputs to limited entry facilities be provided in areas which are not congested since this will reduce the probability of violations of approach lanes or the separated lanes themselves. This would normally require extending the input location upstream to a point where little preferential service is provided initially, but safety and enforcement problems would be greatly diminished.

Traffic Control Related to Enforcement

Traffic control devices are the legal basis for enforcing HOV priority treatment projects. Thus, they should be clear as to the exact meaning of the restrictions. It is important that all traffic control devices be standardized for more universal understanding. The standards presented in the MUTCD appear

quite adequate for this purpose.

The access points to the separated HOV facilities should be clearly signed with time of day and lane-use restrictions. On partially separated facilities, periodic lane-use control signs are also necessary to discourage illegal access. Even on completely separated roadways, consideration should be given to periodic lane-use control signs to serve as reminders of the HOV restrictions. This can aid the enforcement process and make it more efficient in terms of issuing the citation by reducing the amount of discussion between the officer and violator, thereby giving the officer more time for other duties. This practice can also reduce the reluctance of officers to apprehend violators because of verbal abuse.

On the San Bernardino Freeway project, the lane control signing clearly states the restricted use of the HOV lanes during peak periods, however, no clear indications are given for off-peak use. In fact, only buses are allowed use of the HOV lanes during the off-peak, as shown by the project sign in Figure 4. Some motorists failed to discern the distinction between buses and carpools and violated the HOV restrictions in the off-peak periods after seeing the buses using the HOV lanes. A compounding factor was that on many signs, the motorists' view of the times and days was obscured by the sign luminaires. A number of HOV citations were dismissed by the courts because of the confusion. Recently, the HOV restrictions were extended to seven days and the signs were simplified as shown in Figure 4. Not only did this ease the enforcement problem, it greatly assisted weekend recreational traffic which was often heavy enough to be congested due to several large sports centers in the area.

Thus, as an alternative to peak period, weekday-only operations, consideration should be given to making HOV restrictions applicable at all times. This introduces a requirement for additional enforcement during off-peak hours but the benefits to HOVs and elimination of confusion could produce a net improvement and could also reduce or largely eliminate legal challenges. This traffic control consideration is applicable only to separated HOV facilities and does not apply to any other type of priority treatment.

Recommendations for Enforcement

General recommendations on enforcement of HOV priority treatments on freeways are presented on page 49 . In regard to separated HOV facilities, the following specific recommendations are offered.

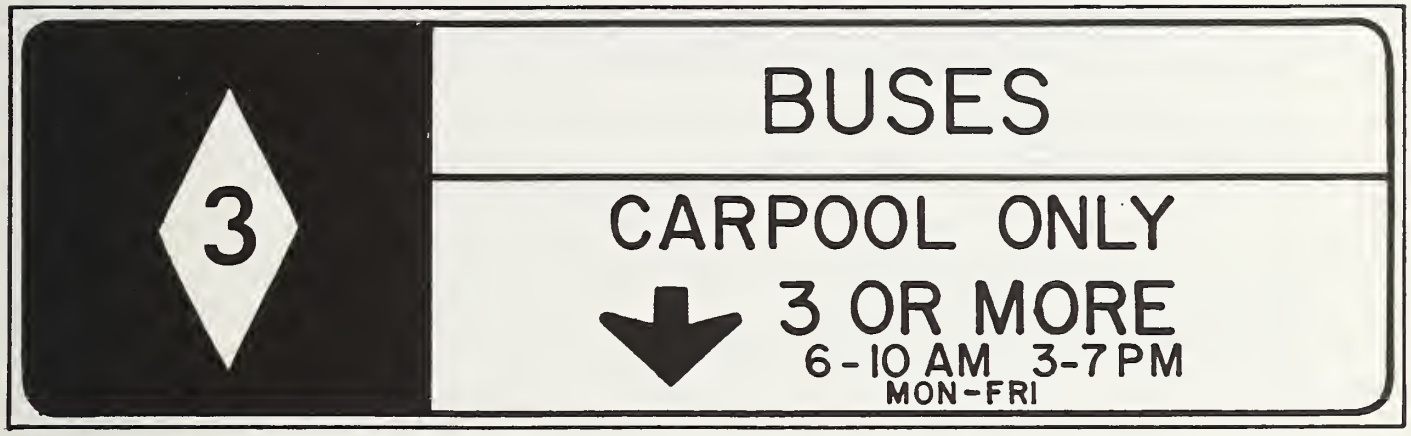
- The facility should have full right and left shoulders. Separation should be accomplished by safety profile concrete barrier walls. Penetrations should be provided in the walls for emergency vehicle access, but these should not be usable by general traffic. Special slots (openings) in the median wall can be provided; however, to allow emergency vehicles to negotiate the maneuver, the median should be widened to provide the necessary turning area. Slots should be barricaded when not in use. If safe slots cannot be provided for trucks and sedans, they should be restricted to motorcycle cuts.

- On partially separated facilities with common shoulders, the shoulders should be flush and easily accessible by disabled vehicles. On the other hand, they should be well delineated to discourage crossing the median shoulder. Implements that could be used for this purpose include solid white edge lines, chevrons or cross-hatching, word messages ("EMERGENCY STOPPING ONLY," "NO CROSSING") and plastic safety posts at regular intervals.

- On reversible facilities, access control must be positive. Use of lane control signals is suggested by the MUTCD and AASHTO but, in addition, gates or barricades should also

FIGURE 4

RESTRICTED LANE SIGNS USED
ON THE SAN BERNARDINO FREEWAY HOV PRIORITY LANE



A. Regulatory Sign Used Initially

B. "Improved" Regulatory Sign

be provided.

- Access locations should be designed to meet the traffic demand but should also be upstream of bottleneck locations if possible.

- Except for some project-specific reason, the enforcement strategy should involve line patrol of the general traffic lanes, while being conscious of the HOV facility. When the incidence of violations appears to be increasing, patrols should be stationed at strategic points on the shoulder of the HOV roadway. This surveillance should vary by timing and should use inconspicuous locations. Apprehension should generally be made on the HOV lane shoulder, unless a convenient exit can be safety reached.

CONCURRENT LANES

Concurrent-flow HOV lane priority projects on freeways generally involve the designation of the median lane(s) for use by buses alone or by buses and carpools. As this treatment commonly addresses "rush-hour" congestion, the restricted operating periods are usually in the peak periods and in the prevailing direction only, although there are exceptions to both of these. The minimum carpool occupancy requirement differs from two to four persons among projects of this type but three persons is the most common. Access to the restricted lane is most often continuous, that is, there is no physical separation or other barrier between the HOV lane and general lanes, and this feature makes concurrent lanes among the most difficult of HOV treatments to enforce. If there is physical separation, the operational, safety and enforcement requirements and problems are drastically different and these were discussed in the previous section. Therefore, this section will address only the continuously accessible configuration.

Concurrent HOV lanes can be created by either reserving an existing lane for HOVs or, more commonly, by constructing new lanes in the median. These two approaches have differing effects from an enforcement point of view. First, the addition of lanes often eliminates or reduces median shoulders or refuge areas which otherwise might be used as vantage points for police patrols and for issuance of citations (although from a practical standpoint the latter is generally not recommended and further discussion of this matter is presented later). Secondly, "taking a lane" for HOVs most likely will increase the congestion in the general travel lanes and will thereby increase the perceived benefits (improved travel time), thus making it more "desirable" for a motorist to violate. The public acceptance of this type of HOV treatment has been much better when new lanes are constructed for the HOVs.

In either case, the resulting geometric configuration is quite similar, except possibly at terminal locations. The inside or median lane operates as the HOV lane and HOVs (and violators) can enter and leave the lane at any point. Such continuous access/agress permits these lanes to serve a variety of origins and destinations along the freeway.

Details of Projects Investigated

Enforcement of concurrent flow HOV lanes on freeways can be very difficult and an important component of the project's operation. Three concurrent flow HOV lane projects were investigated in detail. Project descriptions are given below and in Figures 5 to 7.

- I-95, Miami, Florida (Figure 5)
  This was a 6 to 10 lane urban freeway prior to the HOV lane project. An HOV lane was constructed in the existing median in each direction over a 6.7 mile (10.7 km) section, which is reserved for buses and carpools. The lanes opened in December, 1975, and the minimum carpool occupancy was set at three persons per vehicle (ppv). In January, 1977, the minimum carpool occupancy level was reduced to 2 ppv to increase utilization of the lanes. The current priority time periods are 7-9 AM (inbound, SB) and 4-6 PM (outbound, NB).

- Route 101, Marin County, California (Figure 6)
  This was an eight lane inter-regional freeway connecting San Francisco and suburban residential areas in Marin County. In December, 1974, a new lane was added in the existing median in each direction over a 3.7 mile (6.0 km) section, which was reserved for buses only from 6-9 AM inbound (SB) and 4-7 PM outbound (NB). In June, 1976, carpools of 3 ppv or more were allowed to use the lanes.

- Banfield Freeway, Portland, Oregon (Figure 7)
  This was a 6 to 8 lane urban freeway prior to the HOV project. A new lane was constructed in the existing median in each direction, and the HOV lanes were reserved for buses and carpools of 3 ppv or more from 6:30 to 9:30 AM (inbound, WB) and 3:30 to 6:30 PM outbound (eastbound, PM). The two lanes have different lengths, 3.3 miles (5.4 km) westbound and 1.7 miles (2.8 km) eastbound. The HOV project began in December, 1975.

Table 11 presents the national standards applicable to HOV priority treatments on freeways.

On the I-95 project, the one deficiency in the geometric design is the lack of median shoulders or refuge areas which resulted from the addition of the HOV lanes. This is a serious deficiency and has had an adverse effect on both safety and enforcement. The project is in general conformance with the MUTCD standards for HOV facilities, except that there are no "end of HOV lane" signs. (In the inbound direction, there are "lane ends" signs due to the lane being terminated.)

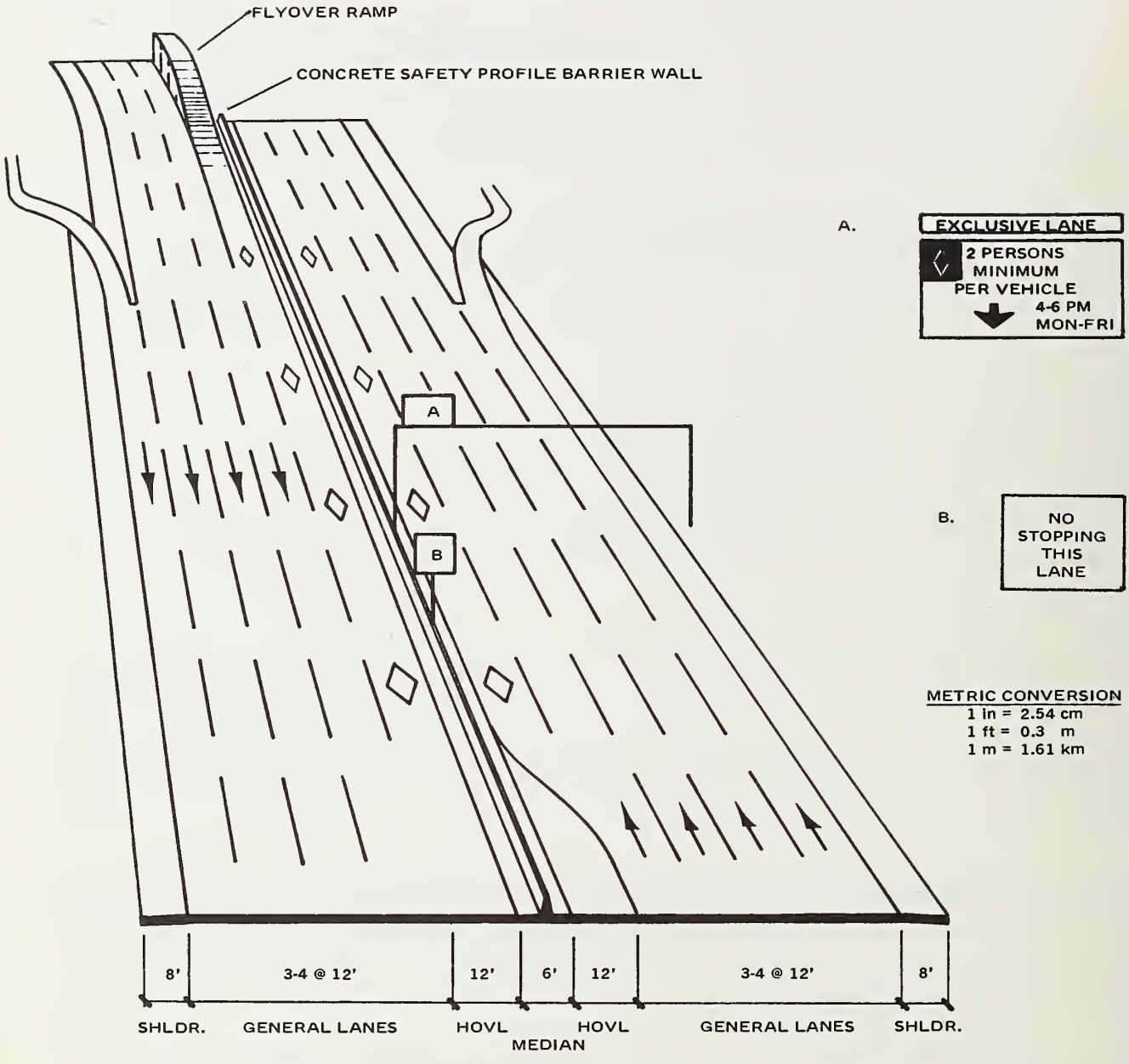
On the Route 101 project, the one deficiency in the geometric design is the narrow width of traffic lanes and left shoulders in sections having an auxiliary lane. The HOV lane signing is non-standard and "end of HOV lane" signs are not used. The diamond marking symbol is not used because of the adverse publicity which this symbol received on the Santa Monica Freeway Diamond Lane project in Los Angeles.

On the Banfield Freeway project, there are several major deficiencies in the geometric design because of the age of the facility. These deficiencies include 11 feet (3.4 m) general lanes, no left shoulder and no continuous right shoulder. Shoulder bays suitable for a refuge area are provided on the right at about 2,000 feet (606 m) intervals. The traffic control devices are in general conformance with the MUTCD standards for HOV facilities.

Operational Results

The extent of the enforcement requirements for an HOV project is dependent in part on the operational effectiveness of the project. The operational results of each project are given in Table 14. Only one peak period is presented—that which experienced the most serious enforcement problem or for which there were the most data. From Table 14, several of the more significant results are:

FIGURE 5
I-95, MIAMI, FLORIDA



AASHTO DESIGN FACTORS

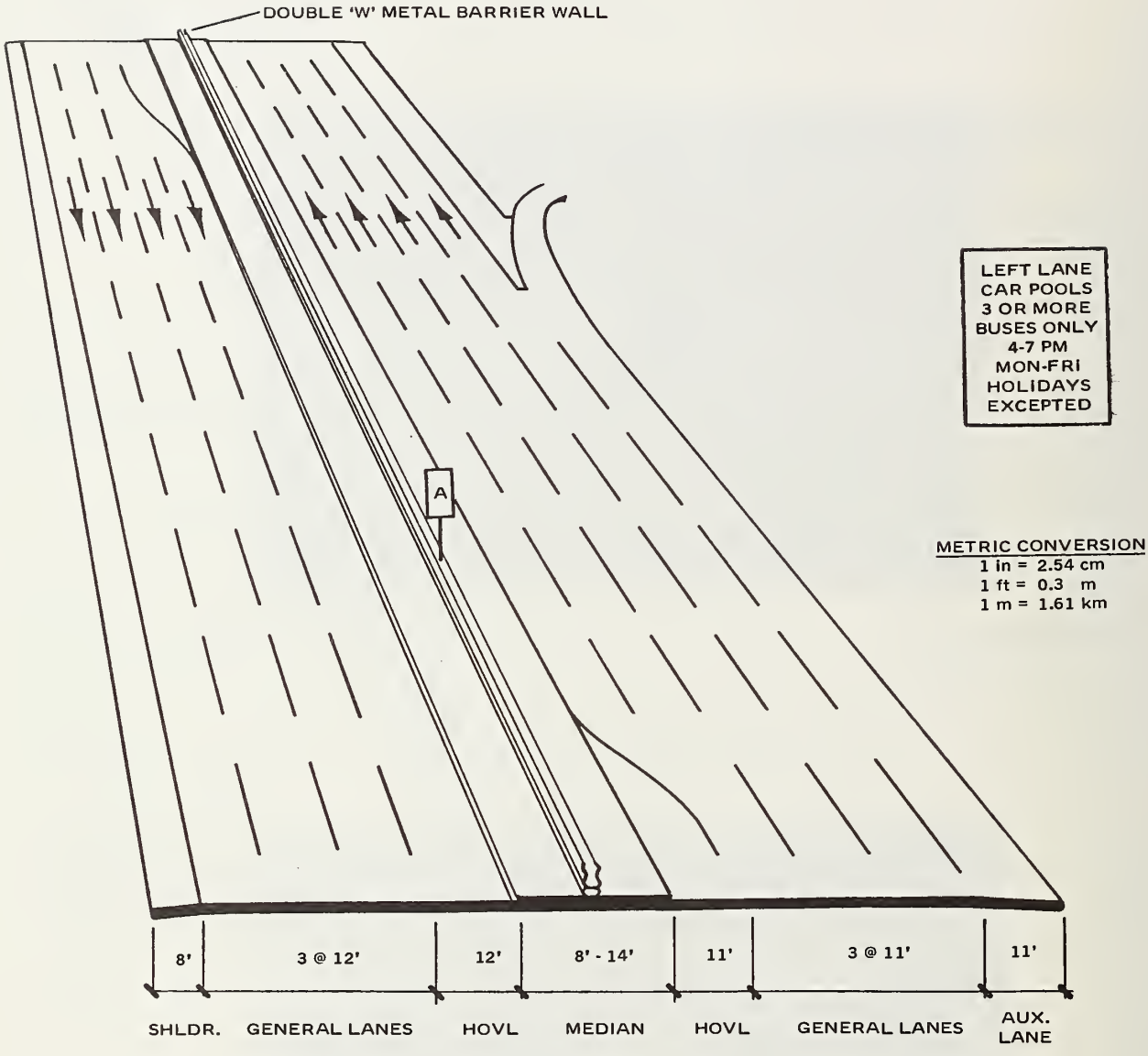
ALIGNMENT: linear
VERTICAL SIGHT DISTANCE: limited by bridges
POSTED SPEED: 55 mph
ROADSIDE HAZARDS: none
OTHER HAZARDS: no left shoulder/refuge area

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: none
ADVANCED WARNING SIGNS: standard
RESTRICTED LANE SIGNS: standard
END OF HOVL SIGNS: none (NB), non-standard (SB)
DIAMOND SYMBOL: standard (250' interval)
HOVL DELINEATION: 3" white skip line

I-95, MIAMI, FLORIDA

FIGURE 6
ROUTE 101, MARIN COUNTY, CALIFORNIA



AASHTO DESIGN FACTORS

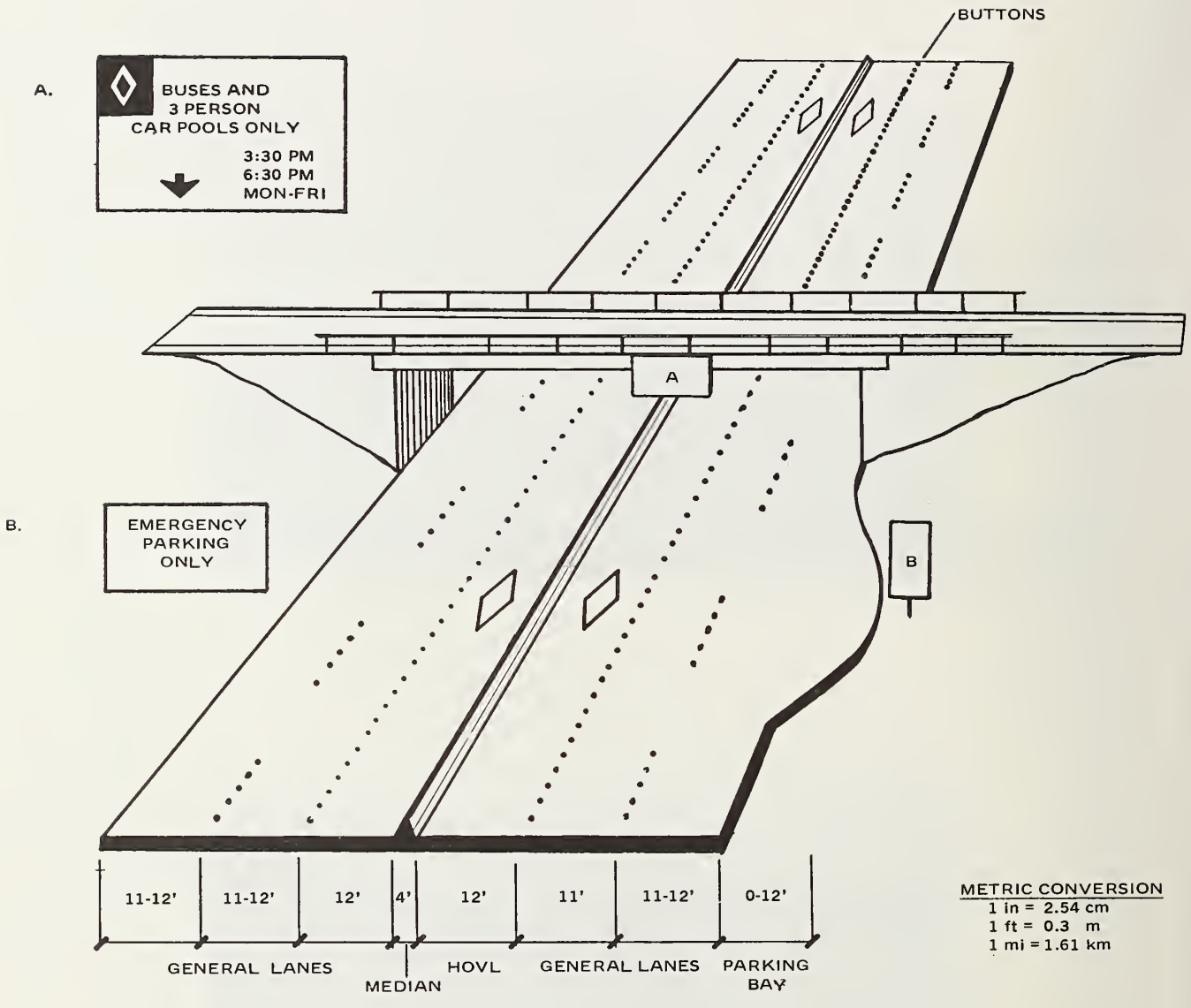
ALIGNMENT: linear
VERTICAL SIGHT DISTANCE: good
POSTED SPEED: 55 mph
ROADSIDE HAZARDS: none
OTHER HAZARDS: raised median

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: none
ADVANCED WARNING SIGNS: non-standard (NB), none (SB)P
RESTRICTED LANE SIGNS: non-standard
END OF HOVL SIGNS: none
DIAMOND SYMBOL: none
HOVL DELINEATION: 4" round buttons in skip pattern

ROUTE 101 (CONCURRENT FLOW SECTION), MARIN COUNTY, CALIFORNIA

FIGURE 7
BANFIELD FREEWAY, PORTLAND, OREGON



METRIC CONVERSION
1 in = 2.54 cm
1 ft = 0.3 m
1 mi = 1.61 km

AASHTO DESIGN FACTORS

ALIGNMENT: curvilinear
VERTICAL SIGHT DISTANCE: good
POSTED SPEED: 45 mph
ROADSIDE HAZARDS: some restricted clearances

OTHER HAZARDS: lane drops

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: none
ADVANCED WARNING SIGNS: standard
RESTRICTED LANE SIGNS: standard
END OF HOVL SIGNS: standard
DIAMOND SYMBOL: 1,000' intervals
HOVL DELINEATION: 4" white raised buttons in continuous line

BANFIELD FREEWAY, PORTLAND, OREGON

- Total traffic volumes increased by 13 percent on both the I-95 and Banfield Freeway projects under a three person carpool definition. By modifying the carpool definition to two persons, the I-95 project experienced increased total traffic volumes by an additional 19 percent with the majority of the increase being in the HOV lane. Total traffic volume decreased on the Route 101 project by 4 percent.

- The HOV lanes illustrate the efficiency of the operation. For the I-95 project, the HOV lane carries 20 percent of the persons in 14 percent of the vehicles. For the Route 101 project, the HOV lane carries 28 percent of the persons in 5 percent of the vehicles. For the Banfield Freeway project, the HOV lane carries 19 percent of the persons in 5 percent of the vehicles. Total passenger throughput (all lanes) increased on all projects ranging from 0.5 percent (Route 101 with bus only lane) to 50 percent (I-95 with two person carpool HOV lane).

- Total auto occupancies increased consistently with all bus/carpool treatments, ranging from 4.6 percent on Route 101 to 10.9 percent on I-95. None of the projects experienced average HOV lane auto occupancies which were higher than the minimum occupancy required, because the violators reduced the average occupancy below the required minimum.

- Travel speeds in the HOV lane on the projects ranged from 50 to 53 mph (80 to 85 kph). The differential in travel speeds between the HOV lane and general travel lanes ranged from 6 mph (10 kph) (Route 101 with bus/carpool HOV lane) to 14 mph (22 kph) (I-95 with three person carpool HOV lane).

- Because of these higher travel speeds, persons traveling in the HOV lane experienced travel time savings over general lane travel. These savings are more appropriately compared on a per mile basis. The savings ranged from 8 seconds/mile (5 seconds/km) on Route 101 with bus/carpool HOV lane to 29 seconds/mile (18 seconds/km) on I-95 with three person carpool HOV lane.

- The accident rates varied dramatically by project. On the I-95 project with a two person carpool HOV lane, the accident rate decreased by 52 percent. On the Route 101 project with a three person carpool HOV lane, the accident rate increased by 209 percent. On the Banfield Freeway project, the accident rate remained essentially the same.

Enforcement Characteristics

Chapter 3 presented details on HOV projects related to 1) the enforcement program, 2) enforcement problems and deficiencies, and 3) the performance of the enforcement program. These enforcement elements are summarized here for the three concurrent flow HOV projects.

- I-95, Miami, Florida
  The Florida Highway Patrol (FHP) employs a routine line patrol strategy on I-95, with officers patrolling in the adjacent general lanes and escorting violators to the right shoulder to issue tickets. The procedure is necessitated by the lack of median shoulders or refuge areas. This HOV facility is extremely difficult to enforce for this reason, as well as a lack of enforcement resources. FHP places a low priority on HOV lane enforcement. About six patrols (sedan and motorcycle) are routinely assigned to the HOV priority section, but they concentrate on other enforcement activities.

- Route 101, Marin County, California
  On Route 101, the California Highway Patrol (CHP) also uses line patrols, but the level of enforcement has increased from three to six or eight officers (both sedan and motorcycle).

TABLE 14

OPERATING CHARACTERISTICS ON CONCURRENT FLOW HOV PROJECTS

VARIABLE	UNIT	PROJECT/CONDITION							
		I-95			Route 101			Banfield Freeway	
		Before	Bus/3 ppv Carpool	Bus/2 ppv Carpool	Before	Bus-Only	Bus/3 ppv Carpool	Before	Bus/3 ppv Carpool
Critical Peak Period	—	4 - 6 PM	4 - 6 PM	4 - 6 PM	4 - 7 PM	4 - 7 PM	4 - 7 PM	7 - 8 AM	7 - 8 AM
Length of HOV Lane	Miles	—	6.7	6.7	—	3.7	3.7	—	3.3
Total Peak Directional Lanes	Lanes	3-4	4-5	4-5	3	4	4	2.3	3-4
Number of HOV Lanes	Lanes	—	1	1	—	1	1	—	1
Volume - All Lanes	Vehicles	11,355	12,825	15,290	13,600	13,137	13,089	3,557	4,025
Volume - HOV Lanes	Vehicles	—	618	2,057	—	191	647	—	203
Volume - HOV Lanes (bus only)	Vehicles	—	23	23	—	148	150	—	23
HOV Lanes/Total Volume	%	—	4.8	13.5	—	1.5	4.9	—	5.0
Auto Occupancy - All Lanes	PPV	1.28	1.37	1.42	1.30	1.30	1.36	1.22	1.26
Auto Occupancy - HOV Lanes	PPV	—	2.23	1.79	—	2.21	2.96	—	2.81
Person Throughput - All Lanes	Persons	14,875	18,221	22,338	24,439	24,567	25,365	4,329	5,611
Person Throughput - HOV Lanes	Persons	—	1,981	4,347	—	5,719	7,172	—	1,067
HOV Lanes/Total Throughput	%	—	10.9	19.5	—	23.3	28.3	—	19.0
Speed - General Lanes	MPH	29.6	35.6	41.6	34.1	43.3	47.6	38.2	37.9
Speed - HOV Lanes	MPH	—	50.0	50.4	—	53.4	53.4	—	51.5
Travel Time - General Lanes	Minutes	13.5	11.3	9.6	6.5	5.1	4.7	5.2	5.2
Travel Time - HOV Lanes	Minutes	—	8.0	8.0	—	4.2	4.2	—	3.8
Accident Rate	Acc/mvm	5.1	4.7	2.4	4.2	9.6	12.8	0.9	0.8

Metric Conversion

1 mile = 1.61 kilometers

This is evidence of the fact that the CHP places a high priority on HOV enforcement. Additionally, the existence of median shoulders makes it possible to monitor the HOV lane from the median. This greatly reduces the propensity for low occupant vehicles to violate the lanes. Apprehension and citations procedures are similar to those on I-95; however, this is less of a problem than on I-95 due to the lower traffic volumes and lower volume/capacity ratios.

- Banfield Freeway, Portland, Oregon
  The Oregon State Police (OSP) uses selective enforcement on the Banfield Freeway, employing line patrols on a pre-programmed basis, but occasionally using hidden patrols to detect violators. Apprehension and citation procedures are standard, except that violators must normally be escorted to one of the right shoulder bays, which may require more time per apprehension than would otherwise be required. The major problem, as on I-95, is the lack of a median shoulder.

Violation data are presented in Table 15. From this table, several of the more significant results are:

TABLE 15

ENFORCEMENT CHARACTERISTICS ON CONCURRENT LANE PROJECTS

VARIABLE	PROJECT/CONDITION									
	I-95				Route 101				Banfield Freeway	
	Bus/ 3 ppv Carpool		Bus/2 ppv Carpool		Bus Only		Bus/ Carpool		Bus/3 ppv Carpool	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
HOV Lane Volume	596	618	1969	2,057	141	191	549	647	203	274
Number of Violators	364	376	703	759	0	34	31	99	21	30
Violation Rate (%)	61.1	60.8	35.7	36.9	0	17.8	5.6	15.3	10.3	10.9
Number of Citations	4		1		na		10		15.8	
Apprehension Rate (%)	0.5		Negligible		na		8		10.7	

- The violation rate varies dramatically between the projects. The Route 101 project with a strong enforcement system and fewest enforcement problems had the lowest overall violation rate (10.2 percent) with the bus-only HOV lane. The Banfield Freeway project experienced a similar overall violation rate (10.7 percent) but it required a selective

enforcement program. The I-95 project, which has low enforcement priority and operational problems, experienced the highest violation rate (61 percent) with the three person carpool HOV lane.

- The violation rates between the AM and PM peak periods were nearly equal except for the Route 101 project where the PM rate is much higher than the AM rate.

- On the I-95 project, the violation rate decreased from 61 percent to 36 percent by lowering the carpool definition from three persons to two persons. This change had the effect of increasing the HOV lane volume by three-fold and the number of violators by only two-fold.

- The enforcement systems on the Route 101 and Banfield Freeway projects, which experienced overall violation rates of approximately 11 percent, apprehended about 8 to 11 percent of the violators. On the other hand, the enforcement system for the I-95 project, which experienced violation rates of 61 percent, apprehended less than 1 percent of the violators.

Other projects employing this HOV treatment generally had violation rates in the range experienced on Route 101 and the Banfield Freeway. For the Santa Monica Freeway in Los Angeles, the violation rate was 15.9 percent and for the Moanalua Freeway in Honolulu, the violation rate was only 6.8 percent.

In summary, concurrent lane projects can be operated effectively and with reasonably few violations, but a variety of problems can result in massive disregard for the HOV restrictions. The next section explores some reasons for success and failure of the various enforcement systems.

Geometric Standards Related to Enforcement

Conventional enforcement of concurrent lanes is primarily accomplished in two ways. First, patrols travel in the adjacent lane and monitor the HOV lane. When a violator is detected, the officer moves into the lane and either follows the offender to an exit or, more often, escorts the violator to the right shoulder by weaving across the general lanes.

Another technique requires a left shoulder or refuge area where patrols station themselves and monitor the lane from a stationary position. These patrols usually employ motorcycles because they are easier to park, are less conspicuous, and are more maneuverable. Once a violator is detected, apprehension can occur in several ways. First, the officer can merely wave-off the violator by indicating he should leave the lane. No further action is taken and the violator is not "punished" other than losing the time advantage (unless he decides to violate again downstream). If apprehension is to occur, the violator can either be flagged into the median area (if speeds permit) or pursued in one of the manners described in the first technique.

In order to utilize the stationary detection technique from the median shoulder, there must be an adequate shoulder or median refuge area where the officer can safely park his vehicle. Furthermore, there must be sufficient shoulder to enable the officer to accelerate to HOV lane speed when he engages in pursuit. Ideally, there would be a shoulder wide enough to enable the officer to bypass any trailing HOVs to catch up with the violator. It is primarily this limitation (shoulder width) which makes the use of motorcycles much more effective than sedans.

The mere presence of the officer in the median shoulder, particularly on a regular basis, can deter

violators since the enforcement operation is conspicuous. Thus, if used regularly, but rotating the location, it can be effective. On the other hand, the use of the median shoulder for enforcement can have deleterious effects on traffic flow. If the officer is too conspicuous from a long distance upstream, violators can exit the lane to avoid detection. The increased lane changing activity by large numbers of violators can introduce substantial safety problems, particularly if the general lanes are highly congested and relative speeds are high. If the violator is pulled over to the median, gawking can result and bottlenecks will develop. Because of this hazard, the more common practice is to escort the offender to the right shoulder. This maneuver is also disruptive but generally less so than stopping on the left. The gawking situation also develops when the citation is issued on the right shoulder, but it is far less severe than when done in the median (which has the additional effect of affecting traffic flow in the opposing direction). It has been suggested that on the Santa Monica Freeway "diamond lanes" project in Los Angeles, the use of the median shoulder for HOV enforcement, with its effects on traffic flow noted above, contributed to increased accidents on the facility.[4]

When officers pursue violators to their exit ramp, effects on safety are minimized, but this technique is extremely costly in terms of the officers' time. Thus, the length of the HOV facility and its proximity to probable exit points can be very critical. A short HOV system terminating in the CBD would produce relatively little lost time. On the other hand, a longer project with many potential destinations further downstream, such as the I-95 project in Miami, may require over 30 minutes to pursue a violator, issue the ticket and return to the project area.

The problem associated with pursuing violators to the right shoulder is clearly a function of the number of lanes to be traversed and the traffic density in those lanes. The problem is further complicated by the fact that two vehicles are making the maneuver rather than one. Public support of the enforcement effort may play an important role in this technique. If support is high, general lane traffic will tend to yield to the police car which can "run interference" for the violator's lane changes. On the other hand, if the public does not support the enforcement effort (i.e. generally opposes the restrictions), it may be very difficult to locate adequate gaps for the weaving maneuver.

With regard to traffic density and laneage, the manner of implementation of the HOV lane plays an important role. For example, on the Santa Monica "diamond lane" project, the HOV lane was "taken" from existing general lanes, so there were only three lanes to traverse rather than four. But the displacement of so many low occupant vehicles to those three lanes substantially increased the congestion. Until congestion was reduced by more restrictive ramp metering, this traffic density posed serious problems to enforcement. In fact, during this period the California Highway Patrol preferred using the median shoulder rather than making this weaving maneuver. Conversely, when the HOV lanes are added, as on the I-95 project, congestion is generally reduced. The latter method of implementation appears to be the preferred situation from the enforcement point of view even though there is an additional lane to traverse.

Since HOV lanes are used by fewer vehicles, speeds may exceed the speed limit during peak hours when freeways are otherwise congested and slow moving. This poses two problems to enforcement. First, enforcement of the speed limit itself, and secondly the erratic behavior of some motorists who

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4. Billheimer, J.W., "The Santa Monica Diamond Lanes: Freeway Accident Analysis," Presented to the 57th Annual Meeting of the Transportation Research Board, Washington, D. C., January, 1978.

desire to travel at high speed and will bypass slower traffic by swerving around the slower traffic by either using the HOV lane (also an HOV violation) or a general lane (such as passing a bus traveling in the HOV lane). These lane changes require long gaps and can involve a significant speed differential between the HOV and general lane, which influences the safety of the maneuver.

In summary, "on line" enforcement techniques are greatly dependent on geometric features. More important requirements, such as total demand, may overrule the desirability of keeping concurrent lane sections more amenable to enforcement, but regardless, careful consideration should be given to the requirements and limitations imposed on enforcement by these major geometric characteristics.

Traffic Control Related to Enforcement

Traffic control devices are the legal basis for enforcement and therefore have great importance. Since concurrent lanes are continuously accessible, the nature of the restriction should be clearly stated ahead of, and within, the priority treatment section to assure that unwary motorists do not mistakenly use the lane. In addition, the stronger the force of the traffic control devices, the less likely there will be unknowing violators. The various classes of traffic control devices include signalization, signing, pavement markings and delineators.

Signalization. Electronic signalization or freeway control systems are neither required by the MUTCD on concurrent lane projects, nor has it been used. There is an instance when it could be useful for safety reasons, which naturally impacts enforcement since enforcement officials are responsible for incident management. Where concurrent lanes have eliminated median refuge areas, there is a high probability of either accidental or voluntary stoppage in the lane. In either case, there is an inherent danger to both the stopped vehicles and oncoming vehicles, particularly when sight distance is limited. Lane control signals, warning beacons, or other real-time electronic control systems can be used to alert oncoming vehicles upstream of the stoppage and reduce the danger of rear-end accidents. This potential safety problem is particularly applicable in off-peak periods and at night.

On-going HOV planning activities in the Atlanta area have considered the possibility of using changeable message speed control signs to regulate the speed differential between the HOV lane and general lanes by reducing the speed limit in the HOV lane in proportion to actual general lane speeds.[5] If such strategies are deployed in the future, additional responsibilities will have to be assumed by the enforcement team.

Signing. In March, 1975, the national standards for HOV signing (and markings) were issued. Many HOV projects were designed prior to this date and the signing on these projects does not generally conform to the new standards. Signing is the only legal basis for issuing citations for HOV violations and therefore must be very clear to the public. The contents of the sign messages on the projects have been discussed in the section on "Details of Projects Investigated."

Since the lanes are continuously accessible, signing must be frequent enough to alert new arrivals on the freeway and to continuously remind through traffic of the continuation of the restrictions.

5. Based upon conversations with T. Wallace Hawkes, Greiner Engineering Sciences and unpublished work for the Georgia Department of Transportation.

Signing can also be aided by pavement markings. The MUTCD does not specify spacing of lane-use signs, however, if the signing is supported by striping and pavement markings, the spacing should be no greater than ½ mile (.8 km). This distance is frequent enough to accommodate most weaves into the HOV lane from entrance ramps across multi-lane freeways in typical peak period operations as well as serving as a periodic reinforcement message.

Signing that provides advanced warning is highly desirable. Its primary purpose is to encourage HOVs to weave to the left well in advance of the HOV lane section, thus reducing the concentration of the weaving area. Half-mile and ¼ mile (.8 and .4 km) warnings would appear to be adequate for these purposes with greater distances used in proportion to the number of lanes involved. Where the HOV lane is converted from an existing general lane, it is equally important to give general (non-qualified) motorists adequate time and distance to exit the lane. A problem can emerge when some motorists begin leaving the lane. As the lane begins to become less congested and "opens up," some short-term travel advantage can be gained by motorists who will remain in the lane until the last point legally possible. At this point, motorists are forced into more aggressive lane changing, which increases the accident hazard, or they are forced into violating the HOV lane. Two actions can be taken to reduce this situation. First, signing can be more aggressive and begin further upstream. For example, a standard advanced warning sign could be followed by supplementary messages such as "OTHER VEHICLES MERGE RIGHT." In order to avoid off-peak problems, this sign could be a blank-out sign which is activated only during priority operations. Another action is to station an officer in the median before the critical point and his presence would discourage this maneuver.

End-of-HOV-lane signing is important to enforcement, particularly if the lane continues as a general use lane. For the I-95 project, neither output terminal is identified as the end of the HOV lane. Inbound, the lane is dropped and the only signing is "LANE ENDS, MERGE RIGHT." It is not clear whether the HOV restrictions carry forward. This is not a problem for habitual drivers, but strangers in the inside general lane could be uncertain as to what action they should take. In the outbound direction, the problem is more serious from an enforcement point of view, although the safety aspect is better. There is no end-of-HOV-lane sign, but a directional sign indicates the left lane is an exit lane to another freeway. This places the status of the upstream half mile (to the previous lane control sign) of the HOV lane in doubt, however, the diamond pavement symbol for the HOV lane does continue to the actual termination point.

Lastly, some problems have developed in the off-peak periods, which did not relate to HOV enforcement, but are clearly matters of great concern. Lane control signs only indicate the proper use during restricted hours. The public must assume that the lane is for general use in the off-peak periods unless the signing indicates otherwise. In the I-95 project, a number of motorists who experienced mechanical problems, stopped in the left lane (since there was no refuge area). Upon questioning by enforcement officers, some motorists believed the lane was a shoulder during the off-peak. This concept was reinforced by the noticeable difference between the new surface and old surface, and the fact that a solid white line, which could also be interpreted as an edge line, separated the left lane from the other lanes. Such stoppages led to several fatal accidents. To alleviate the problem, supplemental signs, reading "NO STOPPING THIS LANE" with an arrow directed at the left lane, were posted on most median sign supports. Additionally, the solid lane line was changed to a skip line. These actions appeared to reduce the frequency of voluntary stops in the left lane, according to local enforcement officials.

Pavement Markings and Delineators. The MUTCD specifies that "appropriate lane striping, word messages and symbology" be used to augment the regulatory signing. The only reference to appropriate striping for restricted-use lanes is that, "A solid white line may be used to separate through traffic from special secondary lanes, such as uphill truck lanes, left or right turn lanes and transit bus lanes."[6] This was the basis of using a solid white lane line initially on the I-95 project. After the safety problem of vehicles stopping in the HOV lane developed, it was concluded that the use of a solid line on a part-time bus and carpool lane was not appropriate and the marking was changed to a skip line.

Because the solid white line also designates an edge line, it is strongly urged that a solid white line not be used as a demarcation for concurrent HOV lanes. Even if the restriction is in effect for 24 hours or for buses only, the conflict with the line's use as an edge line poses potentially serious safety and legal problems. In the hypothetical case in which a lane is designated for buses only at all times, it possibly could be used without resulting legal problems, as evidenced by its wide-spread use for the several other applications as turning and climbing lanes. However, the use of a continuous solid lane line remains questionable from the safety standpoint.

Still, some special demarcation between the HOV lane and general traffic lanes is desirable. A study of the relative effectiveness of the solid and skipped lane lines on the I-95 project suggested that the more restrictive demarcation actually was more effective in reducing lane changes and violations.[7] It is suggested that wider skip lines, such as 8 inches (20 cm) in width or a continuous row of mountable buttons, like those used on the Banfield Freeway, would be appropriate.

Word messages are generally not used on concurrent HOV lanes on freeways and the potential conflict with off-peak utilization would suggest they not be used under normal circumstances. The diamond symbol has been designated as the standard symbology and it should suffice in lieu of word messages. However, there is some reluctance, particularly in California, to use the diamond symbol following the adverse notoriety it gained on the Santa Monica Freeway in Los Angeles. While this may suggest a need to consider another symbol, the diamond has been used without any direct problem all across the nation, even in Los Angeles. It is suggested that the diamond symbol be retained as the standard pavement marking for HOV lanes and publicity be used to improve public recognition.

There is no requirement for physical delineation on continuously accessible concurrent HOV lanes. Buttons or reflectorized delineators can be used as lane lines. Their use may increase the awareness of the HOV restrictions and serve as an accoustical reminder (as the tire passes over them) to violators. This could discourage some violations and could thereby aid in the enforcement process.

Recommendations for Enforcement

General recommendations on enforcement of HOV priority treatments on freeways are presented on page 49 . In regard to concurrent flow HOV lanes, the following specific recommendations are offered.

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6. United States Department of Transportation, (Federal Highway Administration), Manual on Uniform Traffic Control Devices, page 186.

7. Courage, K.G. et. al., University of Florida Transportation Research Center, Traffic Control of Carpools and Buses on Priority Lanes on Interstate 95 in Miami, FHWA Report No. FHWA-RD-77-148, August, 1977.

- The facility should have median shoulders and refuge areas. These are needed both for public safety and to provide an area for officers to monitor HOV operations effectively.

- On projects that operate in both directions during the same hour, median barrier cuts should be provided (if there is a median barrier) to enable motorcycle officers to enforce in both directions. These should not be penetrable by autos and care must be taken to prevent pedestrians from crossing the freeway at such locations.

- Signing and markings should conform rigidly to MUTCD standards, and special supplemental signs should be used as needed. Limits of the HOV priority section should be clearly defined.

- Monitoring by motorcycle officers in the median should be used when possible. If not possible, mobile patrols in adjacent general lanes should then be used.

- Apprehension and detention should not generally be made in the median. Offenders should be pursued to the outside of the freeway and then off the facility in order to minimize disruption to traffic flow. If congestion is heavy in general lanes, extreme care should be exercised in escorting violators off the freeway. Where left hand exits exist downstream, violators should be escorted in the HOV lane to these exits.

- Routine mobile patrols have generally experienced little success in enforcing concurrent-flow HOV lanes on freeways. In view of this, it is recommended that, at a minimum, a concerted and extensive selective enforcement program be used in this case. Even then, there may be a need to provide continuous special enforcement techniques to achieve the desired level of motorist compliance.

CONTRAFLOW LANES

The common application of contraflow HOV lanes is to assign the inside (median) lane in the opposing (off-peak) direction to a special class of vehicles. The contraflow lane is separated from the other travel lanes by insertable plastic posts. If sufficient capacity remains in the off-peak direction, an additional lane can be taken for use as a buffer lane. The vehicles qualified to use the contraflow lane are usually buses, although one project (the Long Island Expressway in New York City) also allows taxis with passengers to use the contraflow lane. Thus, the contraflow lane treatment makes use of surplus capacity in the off-peak direction, thereby increasing the vehicle and person moving capacity in the peak direction by allowing the buses to bypass congested locations.

In practice, most contraflow lane projects operate only during one peak period, because there is either an upstream bottleneck (e.g. tunnel) in the one peak or because other special conditions prevail. Following the peak period, the safety posts are removed, any special traffic control devices are returned to "normal" and the lane is available for general use in the normal direction.

Typically, the contraflow lane section begins or ends upstream of a major bottleneck location such as a bridge, tunnel or toll facility. Buses (and other vehicles if permitted[8]) enter the lane via a median cross-over or by a special ramp and proceed in the peak direction against the flow of off-peak direction

8. Hereinafter, reference will be made only to buses in the contraflow lane although in some cases other classes of vehicles (primarily chaffeur-licensed and operated) are also permitted to use the contraflow lanes.

general traffic, thereby bypassing congested traffic in the peak direction. The output terminal depends on the site and may be a cross-over merging with the general freeway or it may terminate at a bridge, tunnel or toll facility (where the buses can use special lanes or toll booths to gain an additional time advantage). Contraflow lanes have been combined with concurrent flow carpool lanes as on Route 101 in Marin County, California.

Most contraflow lane projects in existence have been implemented on existing freeways and the lane(s) involved were existing. Thus only crossover's and/or special terminal treatments have been constructed. In Houston, more extensive construction is being planned for a new contraflow lane project which will be the first to have an intermediate access/egress point and which will operate during both peak periods.

Details of Projects Investigated

One project, Route 101 in Marin County, California, was studied in detail as part of this research. Because two other contraflow freeway projects have differing operational characteristics and enforcement problems, significant details of these projects are also included in this section. The two other projects are the I-495 approach to the Lincoln Tunnel in northern New Jersey and the Long Island Expressway in New York City. Project descriptions are given below and in Figures 8-10.

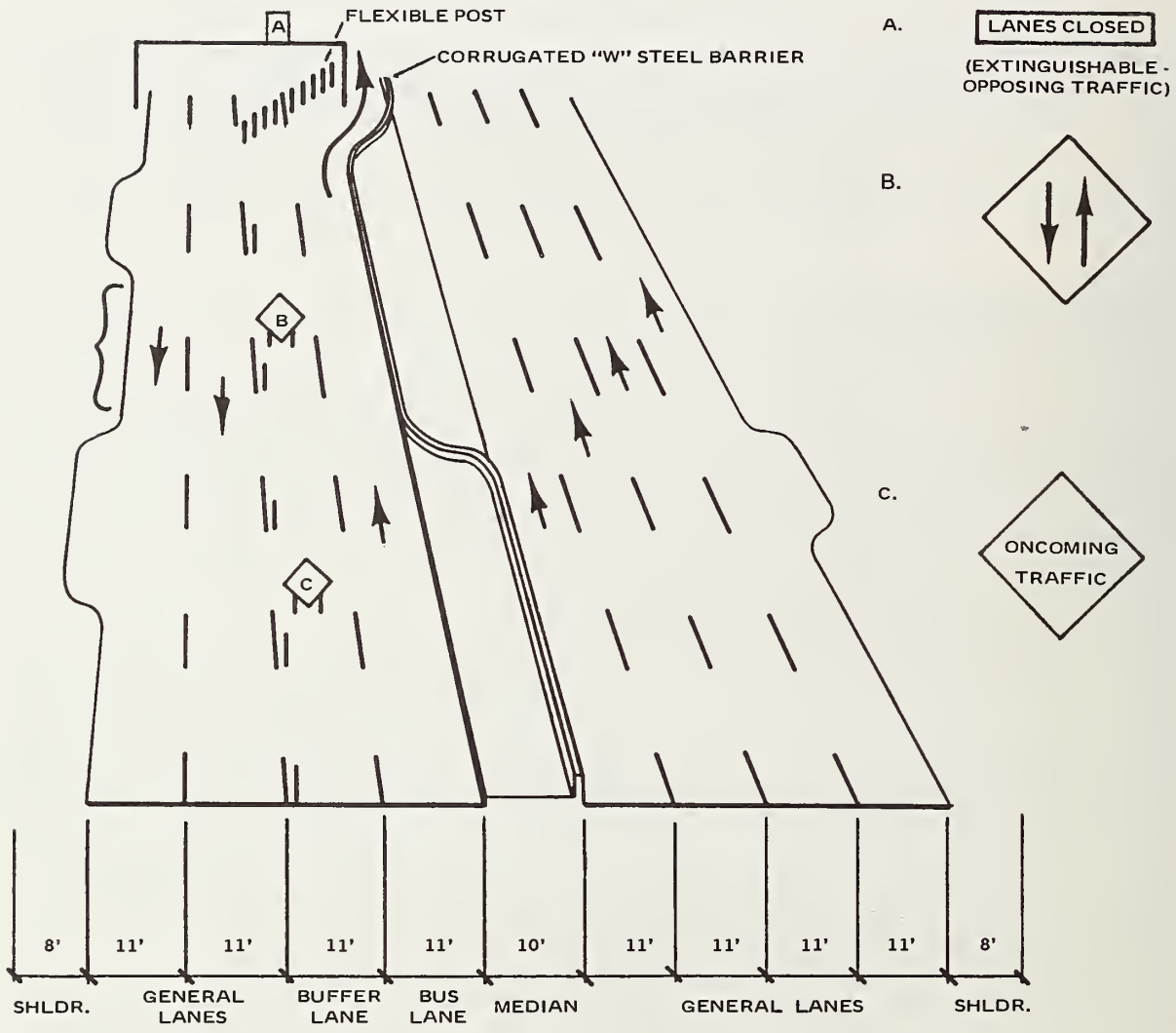
- Route 101, Marin County, California (Figure 8)
  This is an eight lane, inter-regional freeway connecting San Francisco with suburban residential areas in southern Marin County. The priority section begins at the north end of the Golden Gate Bridge and extends for four miles (6.4 km). In September, 1972, the two left lanes of the inbound (SB) roadway were designated as a contraflow lane and buffer lane for exclusive use by buses in the outbound direction (NB). The operating time period is 4-7 PM weekdays, and the priority treatment project operates only in the PM peak. Safety posts as well as two-way traffic signs are installed in the buffer lane. The input is at the Golden Gate Bridge and the output feeds into a concurrent HOV lane for buses and carpools via a median crossover. (see previous section on concurrent HOV lanes of freeways)

- I-495, Hudson County, New Jersey (Figure 9)
  This is a six lane urban freeway which serves as the approach to the Lincoln Tunnel into Manhattan, NYC. In December, 1970, the left lane of the outbound (WB) roadway was designated as a contraflow bus lane during the AM peak period. The 2.5 mile (4 km) contraflow lane is fed by a special ramp in the New Jersey Turnpike Interchange and terminates in the tunnel toll plaza, where buses use separate toll booths. The priority operating period is 7:30-9:30 AM, weekdays. Safety posts are installed along the mainline and overhead lane-use control signs indicate the proper use as shown in Figure 9.

- Long Island Expressway, New York City, New York (Figure 10)
  The physical description of the I-495 project applies similarly to this project. This HOV project was opened in October, 1971, but in September, 1977, taxies with passengers were also allowed to use the contraflow lane. There were no data available to fully evaluate this change in operating strategy, however. The operating hours are 7-9:45 AM, weekdays. Buses enter the contraflow lane via a median crossover and exit two miles (3.2 km) downstream at the Queens-Midtown Tunnel toll plaza.

Table 11 presents the national standards applicable to HOV priority treatments on freeways. Since contraflow lanes are in effect reversible lanes, design and traffic control standards for reversible

FIGURE 8
ROUTE 101 (CONTRAFLOW SECTION), MARIN COUNTY, CALIFORNIA



METRIC CONVERSION
1 in = 2.54 cm
1 ft = 0.3 m
1 m = 1.61 km

AASHTO DESIGN FACTORS

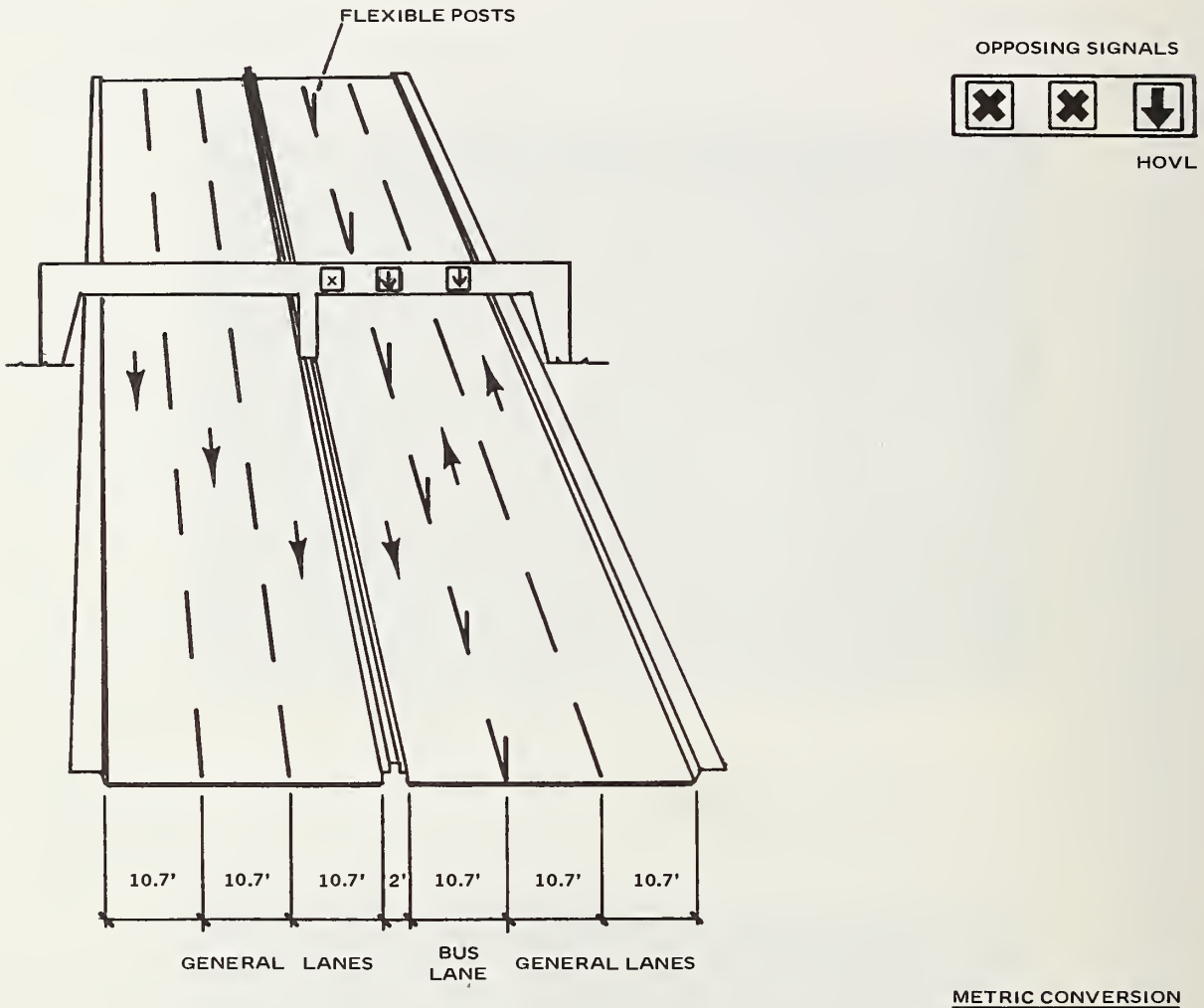
ALIGNMENT: hilly topography
VERTICAL SIGHT DISTANCE: minor deficiencies, tunnel
POSTED SPEED: 55 mph general, 40 mph HOVL
ROADSIDE HAZARDS: hillsides
OTHER HAZARDS: limited shoulders

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: blank-out "lane(s) closed"
ADVANCED WARNING SIGNS: non-standard
RESTRICTED LANE SIGNS: non-standard
END OF HOVL SIGNS: none
DIAMOND SYMBOL: none
HOVL DELINEATION: 4" white skip line, flexible posts in buffer lane

ROUTE 101 (CONTRAFLOW SECTION), MARIN COUNTY, CALIFORNIA

FIGURE 9
I-495 APPROACH TO LINCOLN TUNNEL, HUDSON COUNTY, NEW JERSEY



METRIC CONVERSION
1 in = 2.54 cm
1 ft = 0.3 m
1 m = 1.61 km

AASHTO DESIGN FACTORS

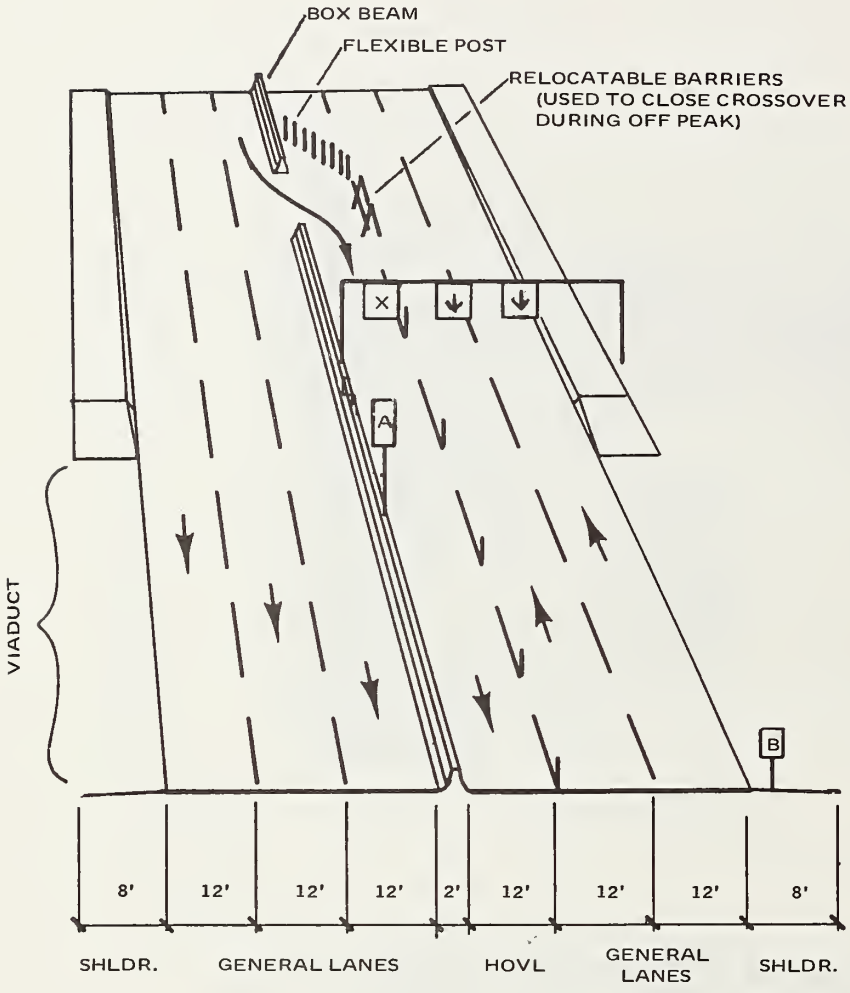
ALIGNMENT: linear except for spiral at toll plaza
VERTICAL SIGHT DISTANCE: limited by low overpasses
POSTED SPEED: 55 mph/inbound; 35 mph HOVL and outbound
ROADSIDE HAZARDS: limited lateral clearance
OTHER HAZARDS: lack of shoulders and median refuge area

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: red x and green arrow
ADVANCED WARNING SIGNS: non-standard
RESTRICTED LANE SIGNS: none
END OF HOVL SIGNS: none
DIAMOND SYMBOL: none
HOVL DELINEATION: 4" white skip line with flexible posts (40')

I-495 APPROACH TO LINCOLN TUNNEL, HUDSON COUNTY, NEW JERSEY

FIGURE 10
LONG ISLAND EXPRESSWAY, NEW YORK CITY, NEW YORK



A.

(HINGED)

B.

(BULB MATRIX-FLASHING)

METRIC CONVERSION
1 in = 2.54 cm
1 ft = 0.3 m
1 m = 1.61 km

AASHTO DESIGN FACTORS

ALIGNMENT: linear
VERTICAL SIGHT DISTANCE: good
POSTED SPEED: 40-50 mph inbound; 35 mph HOVL and outbound
ROADSIDE HAZARDS: none
OTHER HAZARDS: no shoulder over viaduct

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: red 'x' and green arrows
ADVANCED WARNING SIGNS: non-standard
RESTRICTED LANE SIGNS: non-standard
END OF HOVL SIGNS: none
DIAMOND SYMBOL: none
HOVL DELINEATION: double 4" yellow line and flexible posts (40' intervals)

LONG ISLAND EXPRESSWAY, NEW YORK CITY, NEW YORK

lanes are also applicable. None of these projects is in conformance with MUTCD signing requirements for HOV lanes, but as discussed later in the section "Traffic Control Related to Enforcement," the project managers believe that these requirements should not be specified for contraflow HOV lanes. Nevertheless, the discussions below are relative to current MUTCD standards.

On the Route 101 project, the major geometric deficiencies are the lack of right shoulders in certain locations and the median refuge area not being accessible to traffic in both directions. These deficiencies, to a great extent, are due to the mountainous terrain which restricts available right-of-way. The restricted lane signs and HOV lane delineation are non-standard and the diamond symbol is not used. Route 101 does not have lane-use control signals, but the buffer lane provides a place to station removable "TWO-WAY TRAFFIC" and "ONCOMING TRAFFIC" signs.

The I-495 project is deficient in almost every design category because the freeway is over 30 years old. Upgrading would be prohibitively expensive since much of the section passes through a cut in solid granite. To compensate for the deficiencies, both contraflow lane and opposing direction speed limits have been reduced to 35 mph (56 kph). The project does have lane-use control signals, but the HOV lane delineation is non-standard. The restricted lane diamond symbol is not used.

The Long Island Expressway is also an older facility, but the design is superior to the previous project. Still there are no left shoulders or median refuge areas and there are no right shoulders on half of the section which is on a viaduct. The speed limit has been similarly reduced. The project uses lane-use control signals, and the HOV lane delineation is standard having been installed in July, 1977. The restricted lane sign is non-standard and the diamond symbol is not used.

All projects employ "bus lane rules" to further enhance safety. Speed limits for buses have been reduced and bus drivers are required to maintain minimum spacial headways of 200 feet (61 m), and use four-way flashers and headlights to alert oncoming traffic.

The use of yellow plastic safety posts are technically in violation of a recent change in the MUTCD.[9]

Operational Results

The extent of the enforcement requirements for an HOV project is dependent in part on the operational effectiveness of the project. The operational results for each project for the particular peak which it operates are presented in Table 16. From this table, several of the more significant results are:

- Vehicular volumes increased on both projects for which there were "before" data, indicating that the buses removed from the peak direction roadway were replaced by autos to some extent. At the same time the contraflow operation opened on Route 101, a major improvement was implemented in the general lanes which produced additional operational improvements for general traffic. The reduction in capacity in the off-peak directions had minimal operational effects on the three facilities except on accidents.

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9. FHWA, "Official Rulings on Requests for Interpretations, Changes and Experimentations," MUTCD Volume VIII, December, 1977, M-43 (c).

TABLE 16

OPERATING CHARACTERISTICS ON CONTRAFLOW LANE PROJECTS

VARIABLE	UNIT	PROJECT/CONDITION				
		I-495		Long Island Expressway[a]	Route 101	
		Before	Bus-Only	Bus-Only	Before	Bus-Only
Critical Peak Period	—	7:30 - 9:30 AM	7:30 - 9:30 AM	7 - 9:45 AM	4 - 7 PM	4 - 7 PM
Length of HOV Lane	Miles	—	2.5	2.0	—	4.0
Total Peak Directional Lanes	Lanes	3	4	4	4	5
Number of HOV Lanes	Lanes	—	1	1	—	1
Volume - All Lanes	Vehicles	12,792	12,843	9,607	15,392	16,608[b]
Volume - HOV Lanes	Vehicles	—	818	307	—	125
Volume - HOV Lanes (bus only)	Vehicles	763[c]	818	300	120[c]	125
HOV Lanes/Total Volume	%	—	6.4	3.2	—	0.8
Auto Occupancy - All Lanes	PPV	1.60	1.54	1.35	1.28	1.30
Auto Occupancy - HOV Lanes	PPV	—	—	—	—	—
Person Throughput - All Lanes	Persons	51,296	52,875	23,662	24,348	26,428
Person Throughput - HOV Lanes	Persons	—	34,356	11,107	—	5,000
HOV Lanes/Total Throughput	%	—	65.0	46.9	—	18.9
Speed - General Lanes	MPH	10.0	17.2	6.7	24.0	40.0
Speed - HOV Lanes	MPH	—	22.4	34.3	—	36.9[d]
Travel Time - General Lanes	Minutes	14.7	8.7	17.9	10.0	6.0
Travel Time - HOV Lanes	Minutes	—	6.7	3.5	—	6.5
Accident Rate	Acc./mvm	a	3.1	2.1	2.2	2.2

Metric Conversion

1 mile = 1.61 kilometers

a. No before data available.

b. Freeway improvements resulted in increased auto volumes in the after condition. These data exclude the effects of the concurrent HOV lane project added in the north end later.

c. Buses in general lanes in before period.

d. Lower contraflow lane speed due to uphill grade and improvements in general lanes.

TABLE 17

ENFORCEMENT CHARACTERISTICS ON CONTRAFLOW LANE PROJECTS

VARIABLE	PROJECT/CONDITION		
	I-495	Long Island Expressway	Route 101
	Bus Only AM	Bus Only AM	Bus Only PM
HOV Lane Volume	818	307	125
Number of Violators	0	7	0
Violation Rate (%)	0	2.3	0
Number of Citations	0	0	0
Apprehension Rate (%)	—	Negligible	—

- The volume of buses using the contraflow lanes is naturally a function of transit demand. The number of buses varied from 125 on Route 101 to 818 on I-495 in New Jersey. These do not represent large increases over previously existing bus volumes, so the contraflow lanes did not generate large modal shifts; however, the levels of service were increased on all projects.

- The HOV lane utilization illustrates the efficiency of the operation. On Route 101, the HOV lane carries 19 percent of the persons in the peak direction in 1 percent of the vehicles. On I-495, the HOV lane carries 65 percent of the persons in 6 percent of the vehicles. On the Long Island Expressway, the HOV lane carries 47 percent of the persons in 3 percent of the vehicles. Total passenger throughput (all lanes) increased on the two projects which had before data.

- The travel speeds in the HOV lane on the projects ranged between 22 mph (35 kph) on I-495 to 37 mph (59 kph) on Route 101. These speeds, while relatively low for a freeway HOV lane, represent an improvement over the before travel speeds. The differential in travel speeds between the HOV lane and general travel lanes favored the HOV lane by 5 mph (8 kph) on I-495 and by 28 mph (45 kph) on the Long Island Expressway. The differential in travel speeds favored the general lanes by 3 mph (5 kph) on Route 101, as a result of operational improvements in the general lanes and the removal of the buses from the traffic stream.

- Because of the higher travel speeds in the HOV lane, persons traveling in the HOV lane experience travel time savings over general lane travel. For the I-495 project, the travel time savings is two minutes over the 2.5 miles (4 km). For the Long Island Expressway project, the travel time savings is 14.4 minutes over the two miles (3.2 km). On the Route 101 project, because of the slightly higher travel speeds in the general lanes, the travel time loss in the HOV lane travel is only 0.5 minute over the four miles (6.4 km).

- For all three projects, accident rates on the contraflow half of the freeway were significantly (statistically) higher than those in the general prevailing peak direction. This is despite the much higher demand in the peak direction. On the other hand, there were relatively few accidents directly involving the contraflow lane or buses, particularly on Route 101 and the Long Island Expressway. This leads to the conclusion that the capacity reduction, coupled with the presence of oncoming traffic, was somewhat detremental to safety on contraflow facilities. Nonetheless, the overall accident rates compared favorably with concurrent HOV lane projects.

Enforcement Characteristics

Chapter 3 presents details on HOV projects related to 1) the enforcement program, 2) the enforcement problems and deficiencies, and 3) the performance of the enforcement program. These enforcement elements are summarized here for the three contraflow HOV lane projects. Since contraflow lanes for buses-only are virtually self-enforcing, there is little need for enforcement. The enforcement needs are similar on each project.

- Route 101, Marin County, California
  This project demands the least enforcement effort of the three projects. The reasons for this are that a buffer lane exists to accommodate HOV lane problems and the relatively slow speed of the bus lane (particularly when the buses are climbing the Waldo grade) makes it even less "desirable" to violate the bus-only rule. Occasionally the California Highway Patrol (CHP) will station a vehicle at the output of the contraflow lane, but the dearth of violators makes this more or less a perfunctory operation, but serves as a periodic deterrent to potential

violators.

- I-495, Hudson County, New Jersey
  The primary concern on this project is not violations by autos, but that buses, which do not meet Interstate Commerce Commission (ICC) standards of maintenance, dependability and driver training, may use the lane. Such buses would have a higher probability of breaking down, thus creating a blockage of the contraflow lane. This is a particularly serious problem on this project because of the poor geometry associated with the facility. To reduce this possibility, the Port Authority of New York and New Jersey (PANYNJ) and New Jersey State Police station officers at the input ramp to prevent substandard buses (as well as other violators) from using the contraflow lane. Rejected vehicles are diverted from the special access ramp via an "escape hatch" ramp leading back to the general lanes. Even if violators do gain access to the contraflow lane, they are readily detected at the toll plaza at the output of the contraflow lane where officers are directing traffic at all times. The major enforcement problem on this facility is speeding in the bus lane and opposing general traffic lane; however, no active program is employed to reduce this type of violation. Bus offenders are usually identified by radio and officers at the toll plaza verbally warn the drivers.

- Long Island Expressway, New York City, New York
  The New York City Police Department (NYPD) is responsible for enforcement of this project, and the enforcement program is far less formal than on the New Jersey I-495 project. Line patrols monitor the contraflow lane, and there are officers stationed in the toll plaza. These are Tunnel Authority officers, not NYPD, so coordination is less effective than on I-495. The incidence of violations is higher on this project, but most of the violators are actually police officials in unmarked cars who take advantage of their position to violate the bus only rules. Transportation officials actually perform the major "enforcement" task by verbally warning most violators who are detected, but they are powerless to take official action. Speeding is also a significant problem here, but, again, there is no formal campaign to reduce the speeding. The admission of taxis to the contraflow lane on this project has undoubtedly compounded the enforcement problem, but no special enforcement has been implemented for this change.

The violation related results are presented in Table 17. From this table, several of the more significant results are:

- The violation rate (percentage of HOV lane volume that did not qualify) approaches zero on each project. This is because contraflow lanes are essentially self-enforcing due to 1) limited and controlled access points, and 2) the conspicuousness of auto violators. Still, isolated violations have been observed on all projects.

- On the Long Island Expressway project, the violators are police and city officials using the lane in official (unmarked) vehicles, who take advantage of their positions. Since enforcement is the responsibility of the New York City Police Department on this project, the same agency for which most violators work, no official action has ever been taken against the violators.

- Because of the infrequency of violations, there are essentially no HOV citations issued.

In September, 1977, taxis with passengers were also permitted to use the contraflow lane on the Long Island Expressway. On the first day, 50 percent of the taxis had no passengers. The drivers were warned verbally (by transportation officials) and the violation rate decreased. There has been a reported

instance of a taxi driver bypassing a stalled vehicle in the contraflow lane by "ducking" around it in the opposing lanes. This points out the hazard (and attendent enforcement problems) of allowing autos of any type in contraflow lanes, since the drivers are simply not under the same degree of control as bus drivers.

Geometric Standards Related to Enforcement

The single entry/single exit operation of contraflow lanes presents an excellent possibility for stationary enforcement. Although diversion of violators from the input is non-punitive, it guarantees the integrity of HOV operations. Thus, wherever possible, access points should be constructed in such a way as to provide enforcement personnel a location to monitor the input to the lane. Their very presence will usually discourage most violators, but they can also apprehend those who do violate, or radio downstream patrols or toll facility guards to apprehend the violator. Indeed the upstream observer need not be a police official, but may be a civilian observer, so long as the police downstream will react to notification of violators in an official (i.e. punitive) manner. The evidence of violation is as valid at the output as it is at the input, so two-party detection is not constrained by laws that normally preclude tandem enforcement.

The most serious problem facing enforcement of contraflow lanes, especially those with no buffer lane, is not directly related to HOV restrictions but it is in the area of incident management. A stoppage in the lane effectively closes the lane if no area exists for the stalled vehicle to seek refuge. In this event, officers and tow trucks must generally approach the scene from the opposing direction and make a hazardous U-turn into the lane.

A buffer lane is highly desirable from a safety standpoint as it can be used possibly as a refuge area for disabled vehicles or at the very least, it can improve the capability for removing incidents from the contraflow lane. If the buffer lane or adequate shoulder for storing disabled vehicles does not exist, it would be preferable to construct median cross-overs (well designed for safety and non-penetration by general traffic) so that emergency vehicles can approach incidents from the prevailing direction, cross over into the contraflow lane and back to the incident. A buffer lane also affords police the opportunity to pass legitimate HOVs and apprehend violators on the mainline if an adequate apprehension area does not exist downstream.

Traffic Control Related to Enforcement

Each of the three contraflow HOV lane projects employ some non-standard traffic control devices. Specifically, the use of the words "RESTRICTED LANE" and the diamond symbol are not supported by transportation officials associated with these projects. The reason is that these items are more closely identified with restricted treatments which have interaction with general traffic, such as concurrent lanes, and their use is not explicit enough to prevent wrong-way use of contraflow lanes by confused motorists. The consensus is that overhead lane control signals (red "X" and green arrows), or the two-way traffic sign, as in the case of the Route 101 project, should be used along the mainline. At the input terminal, the more explicit message "BUSES ONLY" (or equivalent) is preferred to the superfluous "RESTRICTED LANE (for) . . ." At the output terminal, caution signs alerting the on-coming traffic with other necessary

markings are most appropriate. There is no operational problem associated with the double yellow skip line which is currently the design standard for lane delineation. The traffic control devices recommended by these project managers for contraflow lanes are summarized in Table 18.

TABLE 18
DESIGN RECOMMENDATIONS FOR REVERSIBLE LANES

SIGNALIZATION:	Overhead changeable message lane-use control signals
LANE DEMARCATION:	Double yellow skip line
DELINEATORS:	Reflectorized, flexible yellow tubular posts

Each of the contraflow lane projects placed restrictions on the types of buses, which may use the contraflow lane. Occasionally, unauthorized buses do use the facilities and this is technically a violation. No data were available to quantify these violations but the numbers are believed to be few, especially on the New York area projects where they can be detected at the output terminal. Additionally, on I-495 an officer that is stationed at the input terminal detects most of these violations and forces the buses off the contraflow lane access ramp.

Incident detection and management systems should be well planned because of the potentially serious consequences to traffic flow that can result from an incident in the contraflow lane. Such a system should meet the specific needs of the facility. On I-495 where the roadway is severely restricted to 32 feet (9.8 m) for three lanes, tow trucks which were specially built for tunnels are also used in the contraflow lane section. These vehicles can execute a U-turn in a 20 feet (6.1 m) width in three maneuvers. A standard tow truck would require much more maneuvering, thus disrupting opposing general traffic to a greater extent.

Recommendations for Enforcement

General recommendations on enforcement of HOV priority treatments on freeways are presented on page 49 . In regard to contraflow HOV lanes, the following specific recommendations are offered.

- Lane control signals (red "X" and green arrows) over the contraflow, buffer and adjacent general lanes, double yellow skip lane line, removable safety posts and barricades and changeable message signs at access points are all recommended. HOV lane control signing should be revised from present standards and be tailored to the explicit requirements of the contraflow HOV lane.

- Spacing of lane control devices should have at least one and preferably more devices in view of opposing traffic. Spacing of delineators should be close enough to discourage lane changes and a 40 feet (12.2 m) maximum spacing is recommended.

- A buffer lane should be provided if possible.

- Full right and left shoulders should exist for emergency stops in both the contraflow lane (median shoulder) and opposing general traffic (right shoulder).

- If the output terminal is not inherently suitable for detaining violators (such as a toll plaza) a refuge area should be provided, preferably in the median.

- Speed limits on both HOV and opposing general lanes should be lowered as necessary to reduce relative speeds. Projects with longer headways between the vehicles and without buffer lanes are more critical in this regard.

- Quick reaction incident detection and removal systems should be incorporated into the project. If possible, median cuts should be provided if there is no buffer lane so emergency vehicles can approach in the proper direction; however, these should not be penetrable by general traffic nor present a collision hazard themselves. Care must also be taken to minimize pedestrian use of these crossings. Incident management can be greatly enhanced by the provision of freeway surveillance (electronic sensors or television) and warning beacons should be considered as well, to alert on-coming traffic of downstream incidents.

- The most effective enforcement strategy is to have officers stationed at the access point to divert non-qualified vehicles from using the lane. Depending on the site-specific requirements of the project, this preferred strategy can be selective or continuous special enforcement. Routine freeway patrols should be extremely observant for violators and, more importantly, for incidents. Even accidents in the opposing general lanes can cause swerves into the contraflow lane by vehicles trying to avoid rear end collisons. Violators detected in the contraflow lane should be apprehended in the terminal area if possible.

- Another effective enforcement strategy involves the selective deployment of a stationary patrol at the exit point(s) of the contraflow lane coupled with an easily accessible refuge area. Since violators are usually irrevokably committed to the contraflow lane at a point where downstream enforcement is not visible, the possible need to use more expensive continuous special enforcement upstream can be avoided.

RAMP METERING BYPASS

Ramp metering has been used for nearly two decades to improve general operations on freeways by limiting access onto the mainline of the freeway. This enables vehicles making longer trips to travel at a high level of service and requires motorists desiring to use the facility for shorter trips to pay a "time toll" for the privilege or to seek an alternative route. As an incentive to HOVs, bypass lanes have been constructed which allow these vehicles "free" access to the freeway without the delays encountered by low occupancy vehicles at the ramp signal. The ramp metering bypass (RMB) technique can be used at isolated ramps, or can be incorporated into a series of ramps which collectively form a RMB HOV priority system. RMB can only be functional when metering is active, thus during other periods these lanes may be used by general traffic.

Ramp metering bypass lanes are generally constructed by widening existing ramps, or redesignating one lane of existing multi-lane ramps. Generally, the ramp metering has been in effect when the RMB is implemented, but they can be implemented simultaneously. General lane traffic is metered to release one vehicle at a time and excess demand queues up in the general lane. HOVs enter the ramp in the RMB lane and bypass the queue, proceeding directly to the freeway. RMB lanes can also be metered if the ramp poses a problem to freeway operations. This reduces the level of preferential treatment, but

their metering rate can be higher than the general lane(s) and the smaller numbers of HOVs produce shorter queues. RMB lanes can be the right or left lane depending on the geometric configuration of the ramp. RMB lanes can also be physically separated from the general lanes. This eliminates the interaction between HOVs and general traffic, thereby enhancing the safety and enforcement.

Details of Projects Investigated

Enforcement of RMB lanes can be difficult and can be an important component of the project's operation. Three RMB projects were investigated in detail. Project descriptions are given below and in Figures 11 to 13. Because so many ramps are involved, the projects are only described in general.

- Santa Monica, Golden State and Harbor Freeways, Los Angeles, California (Figure 11)
  A total of 21 ramps on three freeways were studied as part of this research. Implementation was staggered over a period ranging from September, 1974, to July, 1976. Each RMB ramp operates in the priority mode during only one peak period[10] on weekdays. For those operating in the AM peak, the times are 6-9 AM and for those operating in the PM peak, the times are 3-6:30 PM. All but one of these ramps were two-lane ramps with the HOV lane serving as one lane and most of these were widened from one lane. The other ramp was a two-lane ramp which was widened to three lanes and both general lanes are metered. On all of these ramps, both buses and two-person per vehicle (ppv) carpools are authorized to use the HOV lanes. None of these RMB lanes is physically separated from the general metered lane(s).

- North Central Expressway, Dallas, Texas (Figure 12)
  The Mockingbird entrance ramp to the inbound (SB) North Central Expressway was equipped with a bus-only RMB lane in the Spring of 1975. The RMB lane operates during three time periods during weekdays (7-9 AM, 11:15 AM - 1:15 PM, and 4:15-6:15 PM), but the primary time period is the morning peak period. When a bus is on the ramp, its presence is detected by loop detectors and the ramp metering signal displays an extended red signal to stop all general traffic while the bus bypasses the queue and merges at the ramp terminal.

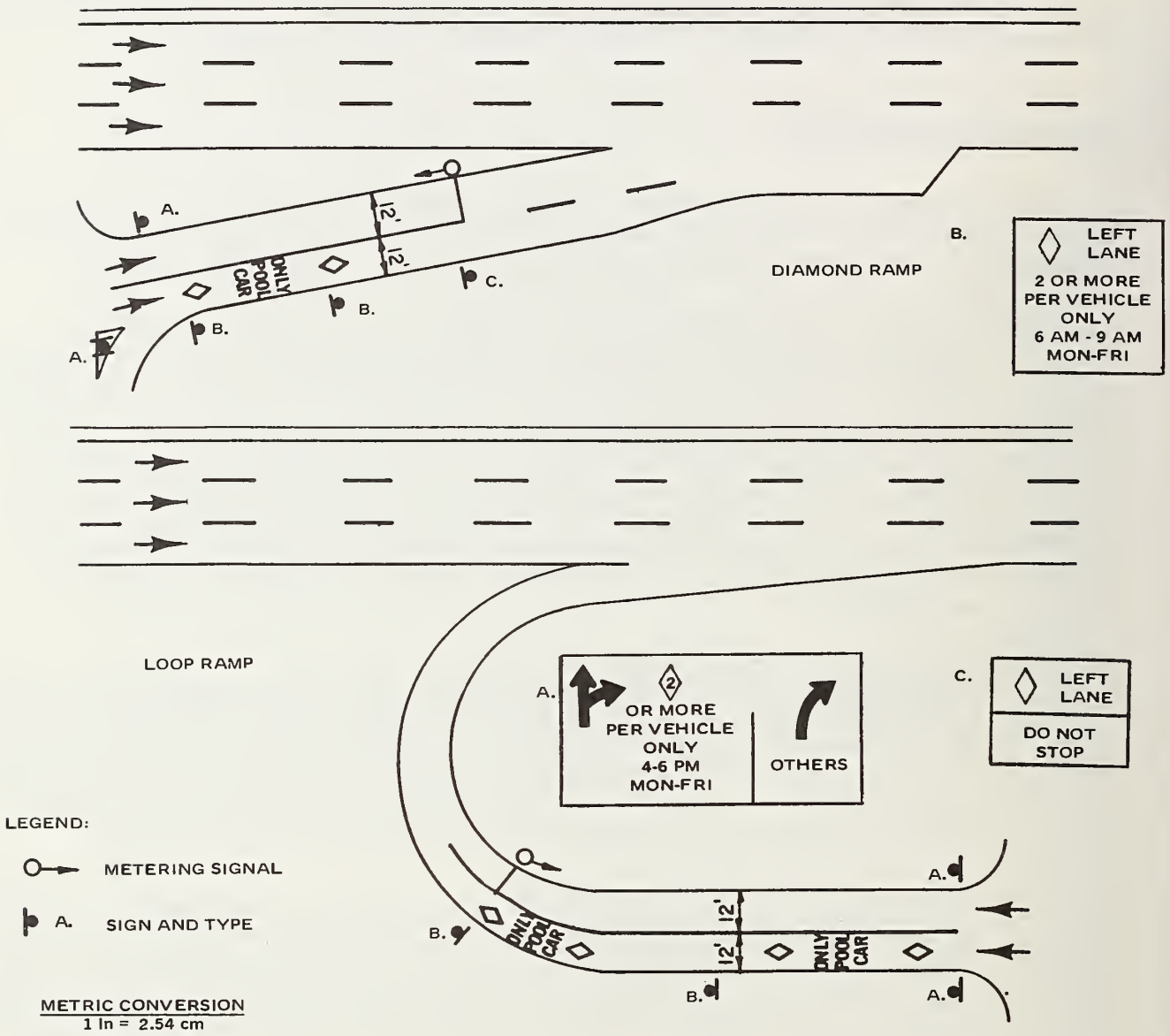
- I-35 W, Minneapolis, Minnesota (Figure 13)
  A total of nine ramps were equipped with RMB in April, 1974. Eight RMB ramps are designated as bus-only and operate in the inbound (NB) direction from 6:30-9:00 AM. The other RMB ramp is designated as bus/carpool ramp with a carpool defined as three persons. This ramp is located in the central business district (CBD) and it operates in the outbound (SB) direction from 4:00-6:30 PM. There are several different geometric/operational configurations to these RMB ramps.

Table 11 presents the national standards applicable to HOV priority treatments on freeways. The general HOV standards are generally applicable with two exceptions. Due to the short length of these ramps, advanced warning of the HOV lane is not necessarily appropriate. It is more important to identify clearly which lane is restricted and the nature of the restriction. Secondly, most ramps narrow from two (or more) lanes and require the HOV and metered lanes to merge. End-of-HOV-lane signs are not appropriate in this case.

On the Los Angeles Freeway projects, some of the ramps having RMB are deficient in one or more areas. Since most RMB lanes were constructed by paving over existing shoulders or widening single lane ramps, there are often no shoulders. Additionally, the curb radii at ramp entries are often too small for

10. In exception to this statement, RMB ramps on the Santa Monica Freeway in Los Angeles operated during both peaks when the "Diamond Lane" experiment was underway.

FIGURE 11
RAMP METERING BYPASS RAMPS, LOS ANGELES, CALIFORNIA



AASHTO DESIGN FACTORS

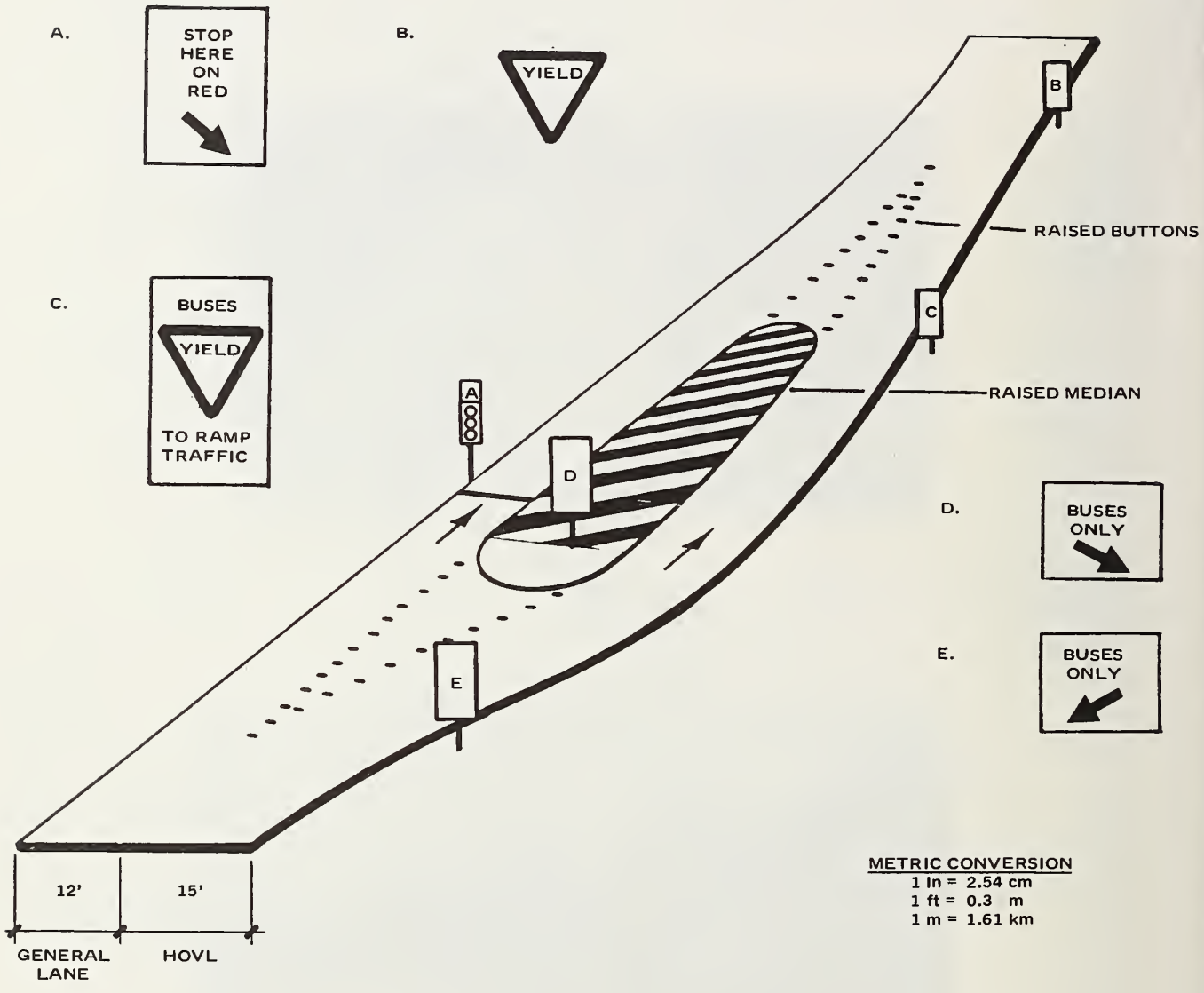
ALIGNMENT: varies
VERTICAL SIGHT DISTANCE: good
POSTED SPEED: none
ROADSIDE HAZARDS: none
OTHER HAZARDS: sharp curb radii and no shoulders

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: ramp meter
ADVANCED WARNING SIGNS: non-standard
RESTRICTED LANE SIGNS: standard
END OF HOVL SIGNS: none
DIAMOND SYMBOL: standard
HOVL DELINEATION: solid white line

RAMP METERING BYPASS RAMPS, LOS ANGELES, CALIFORNIA

FIGURE 12
NORTH CENTRAL EXPRESSWAY, DALLAS, TEXAS



METRIC CONVERSION
1 In = 2.54 cm
1 ft = 0.3 m
1 m = 1.61 km

AASHTO DESIGN FACTORS

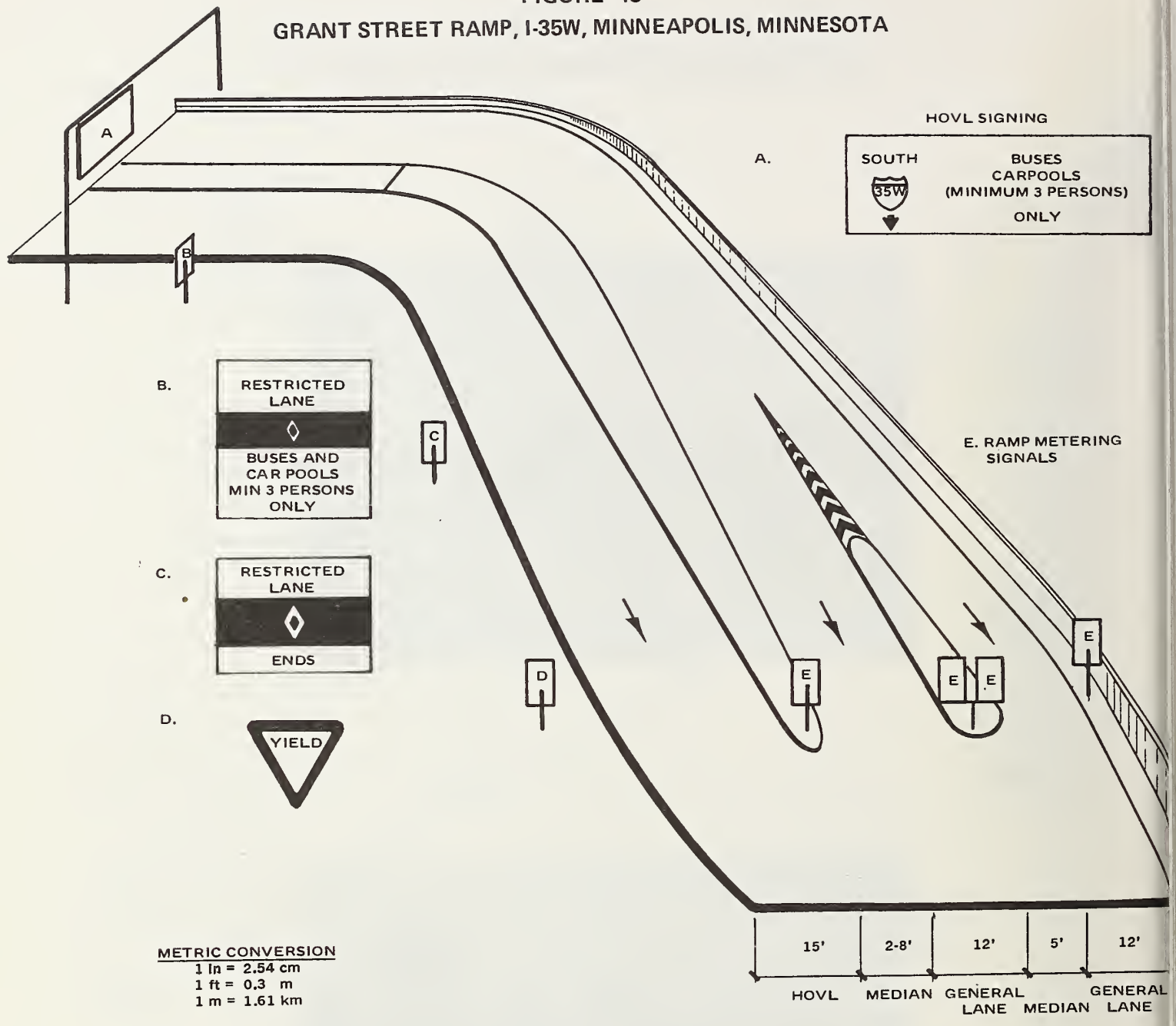
ALIGNMENT: linear
VERTICAL SIGHT DISTANCE: good
POSTED SPEED: none
ROADSIDE HAZARDS: poles within several feet of roadway
OTHER HAZARDS: no left shoulder

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: ramp-metering signals
ADVANCED WARNING SIGNS: none
RESTRICTED LANE SIGNS: non-standard
END OF HOVL SIGNS: none
DIAMOND SYMBOL: none
HOVL DELINEATION: raised buttons in one area

NORTH CENTRAL EXPRESSWAY, DALLAS, TEXAS

FIGURE 13
GRANT STREET RAMP, I-35W, MINNEAPOLIS, MINNESOTA



METRIC CONVERSION
1 in = 2.54 cm
1 ft = 0.3 m
1 m = 1.61 km

AASHTO DESIGN FACTORS

ALIGNMENT: curvilinear
VERTICAL SIGHT DISTANCE: good
POSTED SPEED: none
ROADSIDE HAZARDS: poles within several feet of roadway
OTHER HAZARDS: no shoulders

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: ramp-metering signals
ADVANCED WARNING SIGNS: none
RESTRICTED LANE SIGNS: standard
END OF HOVL SIGNS: standard
DIAMOND SYMBOL: none
HOVL DELINEATION: raised median

I-35W, MINNEAPOLIS, MINNESOTA

Grant Street Bus/Carpool Ramp

Bus-Only Ramp

proper access onto the ramp as right-turning vehicles often have to turn wide into the other lane and this creates a safety hazard. Many of the ramps are simply too short to accommodate the queueing during peak hours and the backup interferes with surface street operation. Any ramps having substandard HOV signing (i.e. missing the diamond symbol) are being upgraded with fully standard signs. On non-separated ramps, solid white lane demarcations and the diamond symbol are used on the pavement. Word messages ("CARPOOL LANE") are used to reinforce the restriction. Metering is generally standard with the exception that on some ramps only one signal head is provided for the metered lane.

On the North Central RMB ramp, there are several deficiencies. There is not a left shoulder adjacent to the general traffic lane, however, there is a right shoulder adjacent to the bus-only lane. During the peak demand for the ramp, the traffic queue can interfere with the surface street operation. The ramp has substandard HOV signing and the diamond symbol is not used. There is no pavement marking for lane delineation between the general lane and bus-only lane. For the metered lane, there is only one signal head provided.

Like the other two projects, the I-35 W ramps having RMB lanes have several deficiencies. Some ramps have shoulder/refuge areas while others do not. The sight distance is restricted on several ramps due to structural impediments. During the peak demand for some ramps, the traffic queues can interfere with the surface street operation. The eight bus-only ramps have substandard HOV lane signing, which must specify that only the Metropolitan Transit Commission's buses may use the RMB lane. The one bus/carpool ramp has a combination of standard and substandard HOV lane signing. The diamond symbol is not used as a pavement marking, but on each ramp, there are transverse markings or cross-hatching at the entrance point to the RMB lane. The word "BUS" is incorporated into this cross-hatching scheme. Several of the ramps, including the bus/carpool ramp, have the RMB lanes physically separated from the general traffic ramp.

Operational Results

The extent of the enforcement requirements for an HOV project is dependent in part to the operational effectiveness of the project. The operational results of each project are given in Table 19. For the RMB ramps in Los Angeles and the bus-only RMB ramps on I-35 W in Minneapolis, the figure presented in the table represents an average figure of all ramps. From Table 19, several of the more significant results are:

- The peak-hour total ramp volume ranges from 400 to 600 vehicles.
- The HOV lane utilization illustrates the efficiency of the operation. On the Los Angeles Freeways, the RMB lane carries 53 percent of the persons in 38 percent of the vehicles. On the North Central Expressway, the RMB lane carries 41 percent of the persons in 4 percent of the vehicles. On the I-35 W bus/carpool ramp, the RMB lane carries 85 percent of the persons in 27 percent of the vehicles and on the bus-only ramps the RMB lane carries 36 percent of the persons in 2 percent of the vehicles.
- On the bus/carpool ramp on I-35 W, the peak-hour total person throughput is over three times greater than the corresponding figures on the other projects. The bus/carpool ramp serves outbound traffic in the proximity of Minneapolis CBD and in the afternoon peak-hour, this ramp handles a high volume of express buses contributing to such a high passenger carrying capability.

TABLE 19

OPERATING CHARACTERISTICS ON RAMP METERING BYPASS PROJECTS

VARIABLE	UNIT	PROJECT/CONDITION			
		LA Freeways[a]	North Central Expressway	I-35 W[b]	
		Bus/2 ppv Carpool	Bus-Only	Bus/3 ppv Carpool	Bus-Only
Critical Peak Period	—	6 - 9 AM; 3 - 6:30 PM	7:30 - 8:30 AM	4:15 - 5:15 PM	7:15 - 8:15 PM
Length of HOV Lane	Miles	—	—	—	—
Total Peak Directional Lanes	Lanes	2	2	2	2
Number of HOV Lanes	Lanes	1	1	1	1
Volume - All Lanes	Vehicles	1,347	438	566	456
Volume - HOV Lanes	Vehicles	509	18	150	10
Volume - HOV Lanes (bus only)	Vehicles	14	11	80	10
HOV Lanes/Total Volume	%	37.8	4.1	26.5	2.2
Auto Occupancy - All Lanes	PPV	1.58	1.26	1.42	1.24
Auto Occupancy - HOV Lanes	PPV	1.76	—	2.88	—
Person Throughput - All Lanes	Persons	2,688	937	3,170	863
Person Throughput - HOV Lanes	Persons	1,431	385	2,681	310
HOV Lanes/Total Throughput	%	53.2	41.1	84.6	35.9
Travel Time Savings (Average)	Minutes	2.1	1.5	0.6	2.9
Travel Time Savings (Maximum)	Minutes	5.3	3.0	1.3	—
Accident Rate	Acc./Year	0.8	—	—	—

a. Data are the average of 21 ramps on Santa Monica, Golden State and Harbor Freeways.

b. Bus/Carpool data are for one ramp; bus-only data are the average of eight ramps.

TABLE 20

ENFORCEMENT CHARACTERISTICS ON RAMP METERING BYPASS PROJECTS

VARIABLE	PROJECT			
	LA Freeways[a]	North Central Expressway	I-35 W[b]	
	Bus/2 ppv Carpool	Bus-Only	Bus/3 ppv Carpool	Bus-Only
HOV Lane Volume	509	18	70	10
Number of Violators	195	7	14	0-1
Violation Rate (%)	38.3	40.0	20.0	2.0
Number of Citations	na	50 per year	20 per year	20 per year
Apprehension Rate (%)	na	2	0-1	0-1

- The average travel time savings experienced by the vehicles using the RMB lanes range from a low of 0.6 minutes (bus/carpool ramp on I-35 W) to a high of 2.9 minutes (bus-only ramps on I-35 W). The maximum travel time savings is approximately double the average travel time savings.

- The lack of data made it impossible to do detailed accident analyses. On the Los Angeles ramps, there was an average of 0.8 accidents per year per ramp. This average accident rate was an eight-fold increase after RMB lanes were added, but the total number of accidents still remained small. The primary problem which was detected related to accidents in the vicinity of the ramp input where both HOVs and general traffic enter the ramps from several surface street approaches. This results in a number of conflicting maneuvers in or near the ramp entry, with an increase in the number of accidents resulting. This led to the conclusion that non-separation of HOVs and general traffic resulted in a more hazardous operation.

Enforcement Characteristics

Chapter 3 presented details on HOV projects related to 1) the enforcement program, 2) the enforcement problems and deficiencies, and 3) the performance of the enforcement program. These enforcement elements are summarized here for the three RMB projects.

- Santa Monica, Golden State and Harbor Freeways, Los Angeles, California
  Because of the variety of ramp configurations, the California Highway Patrol (CHP) uses several surveillance and apprehension techniques within the context of a selective enforcement program. A routine patrol consists of a line patrol that travels the freeway mainline. Because RMB ramps are relatively isolated, a selective enforcement campaign of a stationary patrol has been instituted periodically at these ramps.

- North Central Expressway, Dallas, Texas
  The Dallas Police Department (DPD) uses a selective enforcement program to enforce this RMB ramp. This consists of a stationary patrol located at the end of the ramp. At this location, the officer is out of view until after the motorist is committed to violating the RMB ramp. This operation is instituted one to three times per year, for two to three days in duration. The officer writes eight to ten citations each day. Because of the effectiveness of this hidden location, there is little or no enforcement occurring during the routine patrol, which is a line patrol on the freeway mainline.

- I-35 W, Minneapolis, Minnesota
  The Minnesota Highway Patrol (MHP) uses routine enforcement on the eight bus-only RMB ramps and selective enforcement on the one bus/carpool RMB ramp. Routine enforcement consists of a line patrol that travels the freeway mainline and it can be utilized for enforcement because of the acceptable violation rate experienced by the bus-only RMB ramps. The selective enforcement of the bus/carpool RMB ramp consists of a stationary patrol located at the end of the ramp. At this location, the officer is out of view until after the motorist is committed to violating the RMB restriction. This enforcement tactic is used infrequently.

The violation data are presented in Table 20. From this table, several of the more significant results are:

- The violation rate varies dramatically between the projects. The bus-only RMB ramps on the I-35 W project experienced the lowest violation rate (2 percent) even though it probably received less enforcement attention than the other projects. The bus/carpool RMB ramp also on the I-35 W project has a somewhat higher violation rate (20 percent). The remaining projects—bus/carpool RMB ramps on Los Angeles freeways and the bus-

only RMB ramp on the North Central Expressway experienced violation rates of about 40 percent. On bus-only ramps, violations of the HOV restrictions are lower because violators are more conspicuous. There was no apparent relationship between violation rate and time savings at any of the ramps.

- Overall, the RMB ramps on all projects receive little enforcement attention as shown by apprehension rates of 1 to 2 percent. Since RMB ramps are relatively isolated, enforcement patrols generally must dedicate the time to enforcing them solely in lieu of combining HOV enforcement with other duties while patroling mainlines. Also the number of violations on a RMB ramp can be quite low so that enforcement attention is not required. On the North Central Expressway and I-35 W RMB ramps, the daily number of RMB violators at any one ramp is less than 20.

Geometric Standards Related to Enforcement

As a line patrol of the mainline freeway generally is ineffective for enforcement of RMB ramps, the most common enforcement strategy is stationary patrols on the ramps. This can be stationary patrol cars or motorcycles on the ramp or freeway shoulder. In order to be effective, the stationary patrols should be hidden from sight, have a good vantage point, and have accessible shoulders/refuge areas to detain violators. If the stationary enforcement is not hidden, then all potential violators will observe the officer and will enter the general lane. If the enforcement patrol is stationary, officers usually do not engage in pursuit of violators and wave the violators into a shoulder/refuge area for issuance of the citation. However, patrol cars and motorcycles can be used to pursue the violators.

Physical separation between the RMB lane and the general lanes can aid enforcement and safety by eliminating the opportunity for violators to cut into the RMB lane.

Traffic Control Related to Enforcement

Traffic control devices should be standardized and should clearly state the HOV restrictions. On non-physically separated RMB ramps, the lane demarcation is important. The stronger the force of the demarcation, the less likely violators are to cross the line. In this instance, the use of solid white lines appears to be particularly appropriate. Raised buttons may also be effective. Supplemental pavement markings (the diamond and word messages) also serve to strengthen the force of the regulatory signing.

Integrated traffic control systems, which have the capability of preempting normal metering to allow vehicles in the RMB lane clear access to the merging area, can eliminate merging between these vehicles and general traffic. This consideration is more important from a safety standpoint than enforcement.

A serious problem often develops at metered (not necessarily RMB) ramps with queues backing onto surface streets. Furthermore, drivers often block other lanes of traffic to avoid being set back in the queue (for example, right turns onto the ramp would cut off waiting left turns). This queue poses obvious safety and enforcement problems which are often compounded by the fact that surface street operation may be the responsibility of municipal agencies, whereas the freeway and ramp metering operation may be the responsibility of a state agency.

Violations on RMB ramps take two forms: 1) illegal use of the HOV lane by low occupancy vehicles, and 2) ignoring the red stop signal in the general lanes. The latter is not expressly of concern to this research, but enforcement of both types of violation often overlap. Thus, metering violations cannot be ignored and enforcement of this type of violation must be part of the total enforcement program.

Recommendations for Enforcement

General recommendations on enforcement of HOV priority treatments on freeways are presented on page 49 . In regard to ramp metering bypass for HOVs, the following specific recommendations are offered.

- Provide a physical separation between the RMB lane and the general ramp lane, if space and funding resources permit. If there is no physical separation, then there should be a solid white line demarcation between the lanes, supported by riased pavement buttons for additional emphasis.

- A vantage point should be provided for a stationary officer to monitor the RMB lane out of view of the motorists. Adequate shoulders should be provided for apprehending and ticketing violators.

- The selection of right or left lanes as the HOV lane is important particularly on non-separated RMB ramps. Consideration should be given to access to the ramp, position of signals vis. a vis. the stopped queue and how the two lanes will merge. It is impossible to give specific guidelines in this regard because of the diversity of site specific parameters; however, the most important items to consider are summarized below:

    1) Generally, the preferred configuration is to have the HOV lane on the left as this configuration allows the slower metered traffic to merge with HOV traffic on the left. This technique provides general traffic with a customary merging situation and eliminates the problem of general lane drivers being wary of traffic on both sides.

    2) If metering signals are pole mounted, the preferred lane for metering is the left, so that drivers have a better view of the signal. If the right lane is the metered lane, consideration should be given to providing a narrow median with a signal installed both in the median and on the right. Adequate lighting, reflectorization, channelization and MUTCD policies are needed to prevent collisions with the median or signal standard during hours of darkness.

    3) On curved ramps, the HOV lane should generally be on the outisde of the general lane (i.e. the lane having the larger radius). 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.

- Because of the isolated nature of this priority treatment, continuous enforcement is impractical, particularly if a large number of ramps is involved. Bus-only RMB ramps are less prone to violations, but still require periodic attention. A selective enforcement system should be established whereby each ramp is targeted on a periodic, but random pattern. The enforcement assignment should be dependent on violation levels, which requires some type of data collection scheme.

- Patrols, preferably motorcycle mounted, should station themselves where they can observe the HOV lane and the ramp signal and observe for violators. Preferably, the position is hidden from view. Once a violator is detected, he should be pursued or (if possible) waved over to the shoulder. Tickets should be issued in view of the ramp traffic for maximum effect since the disruption to ramp traffic is not as detrimental as it is on the mainline.

EXCLUSIVE TOLL PLAZA LANES

A toll plaza is inherently a bottleneck on a freeway. In such instances, the capacity of the toll plaza is generally equal to or less than the upstream demand, resulting in extensive queueing in peak periods. Exclusive lanes for HOVs enable these vehicles to bypass the queue and gain access to the toll facility with less delay.

This HOV priority treatment is relatively simple to implement if lanes and/or toll booths are re-designated from general traffic use to exclusive use by HOVs. Since toll plaza configurations vary greatly, there is no "typical" manner of implementing restricted lanes or booths for HOVs. On the Evergreen Point Bridge approach in Seattle, the right shoulder is used as a bus/carpool lane to enable these HOVs to bypass the queue; however, there is no reserved toll booth so HOVs must merge with the right general lane to use a toll booth. In two projects in the New York City area (I-495 approaches to the Lincoln and Queens-Midtown Tunnels), buses approach the toll plaza in contraflow lanes and proceed through the toll station using restricted toll booths. In the San Francisco-Oakland Bay Bridge (SFOBB) toll plaza, three lanes of the 17 approach lanes are reserved for buses and carpools. The HOV lanes continue through the toll station where HOVs are not required to stop, as carpools pay no toll and bus companies are billed based on scheduled crossings. In addition, a freeway metering station has been installed to improve flow on the bridge and HOVs are processed through this metering station without stopping.

Thus, exclusive toll plaza lanes serve several purposes. They allow HOVs to 1) bypass queues on the approach, 2) move through the toll station with minimal delay, and 3) gain preferential access to the toll facility itself.

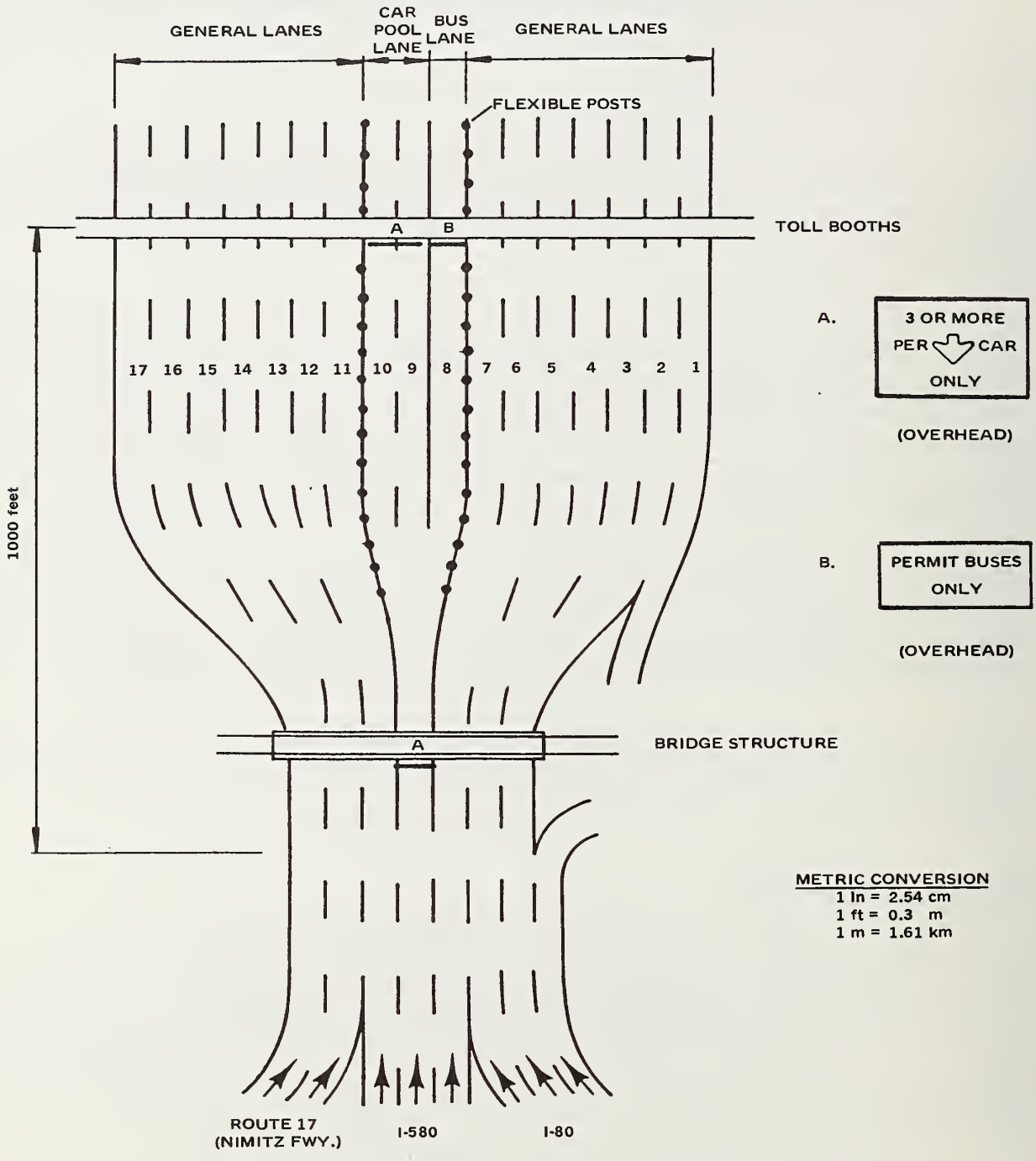
Details of Project Investigated

Enforcement of exclusive toll plaza lanes is relatively easy. For this reason only the San Francisco-Oakland Bay Bridge (SFOBB) toll plaza HOV lanes project was investigated in detail. This project is unique since it combines concurrent HOV lanes on the approach to the toll plaza and preferential access to the bridge by not stopping HOVs at the downstream metering station. It also has a higher probability of violations than the other projects previously mentioned. The project description is given below and is illustrated in Figure 14.

- San Francisco-Oakland Bay Bridge, California (Figure 14)
  The San Francisco-Oakland Bay Bridge spans five miles (8 km) connecting these two major cities. It is a toll bridge with 17 toll booths operating in the inbound direction (to San Francisco). After the toll booths, the freeway narrows down from the 17 lanes to 5 lanes on the bridge in a distance of just 3,800 feet (1,158 m). To alleviate merging problems and control the volume of traffic on the bridge, a freeway metering system was installed 1,000 feet (303 m) downstream of the toll booths. Beginning April 20, 1970, the center lane of the 17 inbound lanes were designated as a bus-only lane. On December 8, 1971,

FIGURE 14

SAN FRANCISCO - OAKLAND BAY BRIDGE TOLL PLAZA, OAKLAND, CALIFORNIA



AASHTO DESIGN FACTORS

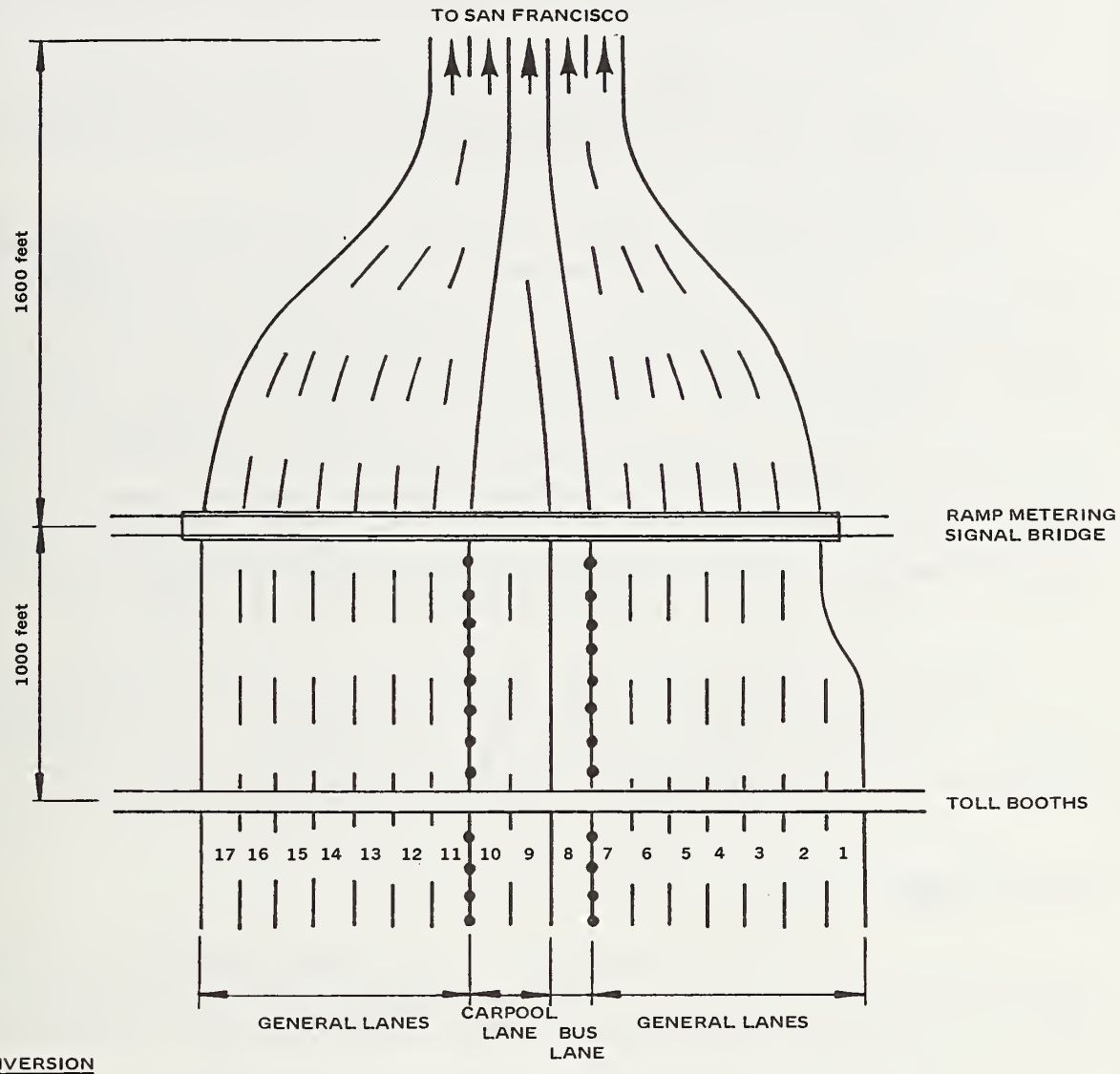
ALIGNMENT: s-curve through toll plaza
VERTICAL SIGHT DISTANCE: good
POSTED SPEED: 35 mph
ROADSIDE HAZARDS: none
OTHER HAZARDS: lane expansion (7 to 17) and reduction (17 to 5)

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: ramp metering of general lanes
ADVANCED WARNING SIGNS: non-standard
RESTRICTED LANE SIGNS: non-standard
END OF HOVL SIGNS: none
DIAMOND SYMBOL: none
HOVL DELINEATION: solid white line with flexible posts

FIGURE 14 (CONT.)

SAN FRANCISCO - OAKLAND BAY BRIDGE TOLL PLAZA, OAKLAND, CALIFORNIA



METRIC CONVERSION

1 In = 2.54 cm
1 ft = 0.3 m
1 m = 1.61 km

the HOV operating strategy was modified whereby two additional center lanes were designated for carpools of three or more persons. The ramp metering system became operational on March 12, 1974. The vehicles in the HOV lanes pay no toll and are not delayed by the ramp metering system. This HOV operating strategy is only in effect in the inbound direction from 6:00 AM to 6:00 PM, but the main period of interest is the AM peak period (7-9 AM).

Table 11 presents the national standards applicable to HOV priority treatments on freeways. Toll facilities are not covered explicitly by AASHTO standards, but the guidelines shown are deemed to be applicable to the extent possible in such a special section of freeway.

There are no significant design deficiencies on the SFOBB project other than the necessary expansion of seven to 17 lanes and subsequent convergence or taper to five lanes. The HOV project predates MUTCD standards on traffic control devices for restricted lanes and has not yet been upgraded. The major deficiencies are in non-standard signing and the absence of the restricted lane diamond symbol. The absence of the diamond is due to the reluctance of the California Department of Transportation to use this symbol following the adverse publicity the symbol received on the Santa Monica "Diamond Lane" project in Los Angeles. Originally the advanced warning signs read "CARPOOL LANE AHEAD" followed by "THREE OR MORE PER CAR AHEAD." The word "ahead" was ambiguous and this word was later replaced by "BEGINS 1,500 FT." and "1,000 FT.," respectively. There are no signs within the restricted area except over the toll booths. During the off-peak periods, some of the upstream safety posts are removed and the hinged carpool lane signs are folded so as to appear blank.

As carpools are not required to pay tolls, they are free to pass through the toll booths without stopping. The slots are narrow and there is always the possibility of conflicts downstream so the speed limit in the carpool lanes is reduced to 15 mph (24 kph) through the booths. There is no speed limit imposed on the buses, but the bus operators are instructed to restrict their speed.

Operational Results

The extent of the enforcement requirements for an HOV project is dependent in part on the operational effectiveness of the project. The operational results of the SFOBB project are given in Table 21. There were actually four operating conditions, or stages, of interest. These are:

1) Before Stage—general operations prior to any HOV priority treatment,

2) Bus-Only Stage—one lane (No. 8) was reserved for buses,

3) Bus/Carpool Stage—in addition to the bus lane, two carpool lanes (Nos. 9 & 10) were reserved for carpools of three or more persons, and

4) Bus/Carpool and Metering Stage—the HOV lanes are allowed non-stop passage through the metering station, which was installed to control the volume and the merging as the facility narrows from 17 to five lanes.

Data on the before condition was limited due to the age of the project. The HOV lanes operate inbound from 6 AM to 6 PM, but the primary area of interest is the 7-9 AM peak period. From Table 21, several of the more significant results are:

TABLE 21

OPERATING CHARACTERISTICS ON SFOBB EXCLUSIVE TOLL PLAZA LANE PROJECT

VARIABLE	UNIT	PROJECT/CONDITION			
		SFOBB Toll Plaza Lanes			
		Before	Bus-Only[a]	Bus/3 ppv Carpool[a]	Bus/3 ppv Carpool[b]
Critical Peak Period	—	6 - 9 AM	6 - 9 AM	6 - 9 AM	6 - 9 AM
Length of HOV Lane	Miles	—	1.1	1.1	1.1
Total Peak Directional Lanes	Lanes	17	17	17	17
Number of HOV Lanes	Lanes	—	1	3	3
Volume - All Lanes	Vehicles	22,820	23,001	22,694	22,346
Volume - HOV Lanes	Vehicles	—	767	2,827	3,338
Volume - HOV Lanes (bus only)	Vehicles	—	542	509	406
HOV Lanes/Total Volume	%	—	3.3	12.5	14.9
Auto Occupancy - All Lanes	PPV	na	1.31	1.42	1.50
Auto Occupancy - HOV Lanes	PPV	—	1.31[c]	3.23	3.29
Person Throughput - All Lanes	Persons	na	49,069	50,914	46,908
Person Throughput - HOV Lanes	Persons	—	19,942	26,875	23,718
HOV Lanes/Total Throughput	%	—	40.6	52.8	50.6
Speed - General Lanes[d]	MPH	na	15.1	28.6	na
Speed - HOV Lanes[d]	MPH	—	31.5	38.2	na
Travel Time - General Lanes[d]	Minutes	na	15.5	8.2	na
Travel Time - HOV Lanes[d]	Minutes	—	7.4	6.1	na
Violation Rate	%	—	29.3	7.1	5.6

Metric Conversion

1 mile = 1.61 kilometers

a. HOV priority at toll plaza.

b. HOV priority at toll plaza and metering station.

c. These are violators.

d. Speed and travel time based on 3.9 mile (6.3 km) section from junction of I-80 and I-580 to Treasure Island.

TABLE 22

ENFORCEMENT CHARACTERISTICS ON SFOBB EXCLUSIVE TOLL PLAZA LANES PROJECT

VARIABLE	CONDITION		
	Bus Only	Bus/Carpool (Toll Booth)	Bus/Carpool (Toll + Meter)
HOV Lane Volume	767	2,827	3,338
Number of Violators	225	201	192
Violation Rate (%)	29.3	7.1	5.6
Number of Citations	na	6	7
Apprehension Rate (%)	na	2.9	3.6

- The total peak period volumes did not vary substantially from stage to stage. In the bus/carpool and metering stage, the average hourly volume per general lane is 679 vehicles and the average hourly volume per carpool lane is 733 vehicles. The general lane rate is primarily a function of capacity, while the carpool lane rate is primarily a function of demand.

- Passenger utilization of the HOV lanes is excellent on the SFOBB project. Although no data were available to compare total throughput with the before condition, 41 percent of the passengers were moved in only 3 percent of the vehicles during the bus-only condition. After carpools were allowed to use HOV lanes these percentages increased to 53 percent and 13 percent, respectively. Total passenger throughput increased by 4 percent. When metering was added, the total persons throughput declined by 8 percent, but this was primarily the result of the opening of the Bay Area Rapid Transit (BART) System.

- Travel speeds in the HOV lanes for the different stages ranged from 32 to 38 mph (52 to 62 kph). The differential in travel speeds between the HOV lanes and general travel lanes varied from 16 mph (26 kph) in the bus-only stage to 12 mph (19 kph) in the bus/carpool stage.

- Because of these higher travel speeds, persons traveling in the HOV lane experienced travel time savings over general lane travel. In the bus-only stage, the travel time savings was 8.1 minutes over the 3.8 miles (6.1 km). For the bus/carpool stage, the travel time savings was 2.1 minutes. As previously stated, it is believed that metering has resulted in additional savings especially for HOVs, although no studies have been conducted to confirm this suspicion.

- Accident rates varied somewhat from stage to stage. The rates shown in the table include all accidents and travel for a 2.8 mile (4.5 km) section beginning upstream of the toll booths and extending onto the bridge. Overall, the accident rate increased with successive HOV priority treatments until metering was added, however, the change from the before to bus-only stage was not statistically significant (probably due to a low sample size in the before condition). The major cause of the increased rates was congestion. The redesignation of first one and then two lanes from general-use to HOVs undoubtedly contributed to this congestion. Metering had a positive effect, particularly on the bridge itself. The overall accident rate declined by 43 percent after metering was installed. This decrease is statistically significant at the 99 percent level of probability.

Enforcement Characteristics

Chapter 3 presented details on HOV projects related to 1) the enforcement program, 2) the enforcement problems and deficiencies, and 3) the performance of the enforcement program. These enforcement elements are summarized here for the SFOBB project.

The California Highway Patrol (CHP) places high emphasis on enforcement of the HOV restrictions. In addition to the routine stationary and line patrols in the toll plaza area and on the bridge itself (5-6 sedans), selective HOV enforcement is employed periodically whenever the violation rate exceeds 10 percent. Selective enforcement is employed about twice a month on the average. The specific tactics used involves the closing of either a carpool lane or an adjacent general lane just beyond (downstream of) the toll booth. This closed section is used for storing violators, which are detected while passing through the toll booths, and the violators are ticketed while waiting in this area. This "shunt" lane operation requires 3-4 additional officers. This technique is extremely effective and a

high percentage of violators are apprehended on the days it is employed.

On other days when routine enforcement is used, there are several problems. First, the violators may move into the HOV lanes at the beginning or "jump" into the lane either upstream or downstream of the toll booths. The latter actions are hazardous because of the speed differential. The second problem is apprehension. Officers usually station themselves on the left shoulder and when a violator is detected, he is pursued and escorted to either shoulder. This weaving section is short and is compounded by the tapering of 17 lanes down to five.

The pertinent enforcement data which were available are reported in Table 22. The violation rate was relatively high (29 percent) during bus-only operations due to the relatively large number of violators compared to buses. When the system was opened to carpools, the violation rate declined to a satisfactory level. Metering was also effective in lowering the violation rate because of additional delineation and the closer proximity of the queueing to the toll booths.

On the particular days when selective enforcement took place, (about twice a month) the apprehension rate approximated 50 percent compared to a three percent apprehension rate when routine enforcement was used. Of the violators apprehended, approximately 60 percent were issued formal summonses and 40 percent were issued warnings. During the bus/carpool stage, and on days when enforcement is present, the violation rate was 18 percent lower than on days without selective enforcement. After metering was added, this differential in the violation rate due to selective enforcement increased to 47 percent.

On the other projects, such as the New York area projects, autos are sometimes allowed to use the bus toll booths by officers on station, but there are virtually no elective violations since these officers direct traffic throughout the peak.

In summary, exclusive toll plaza lanes for HOVs can operate efficiently and with relatively few violations. Selective enforcement when used periodically, can maintain a sustained violation rate which is lower than 10 percent.

Geometric Standards Related to Enforcement

It is highly desirable to provide a refuge area or shoulder adjacent to the HOV lanes for enforcement to monitor operations. Additionally, a refuge area or shoulder adjacent to the HOV lanes would be extremely useful as a place to detain violators. This area or areas could be used by both routine daily patrols as well as by selective enforcement teams. Such an area places additional right-of-way requirements on the facility or it may reduce the capacity of existing facilities.

Permanent physical separation would also reduce enforcement problems since the lanes would then have a "tunnel" effect and violators could only enter at one point. In this event, officers could more easily be stationed at the toll plaza since escape and evasion would be eliminated. This would have some impact during off-peak periods and a barrier wall beginning in the middle of a wide facility could pose safety problems; however, the lower speed in these areas would offset the safety hazard to a certain degree. Less restrictive, but safer delineation such as raised curbs may also be effective.

Traffic Control Related to Enforcement

Traffic control devices have perhaps a greater bearing on enforcement of these priority treatment projects than geometrics. When the HOV lanes begin within the general traffic flow lanes, they must be well identified and sufficient warning must be given so that non-HOVs can avoid them without difficulty.

Signing is one of the most critical elements. Since regulatory lane-use signs are the legal basis for enforcement, they should be placed well upstream for sufficient advanced notice, along the HOV lane as continuous reminders and at the toll booths to avoid confusion.

Pavement markings should reinforce the signing by the use of proper demarcation, symbols and messages. On this treatment it may be appropriate to use the solid white line to discourage lane changes in the vicinity of the toll booths. Indeed, the SFOBB project does use solid lines on each side of the HOV lanes as well as between some of the general lanes to separate groups of lanes which first diverge then later converge. The effectiveness of the solid white line may be reduced because of existence of bumper to bumper traffic and motorists would not be able to see the line.

Delineation is important to discourage violations. Spacing should be close enough to act as a positive deterrent in the vicinity of the toll booths, about 20 feet (6.1 m) maximum. Further upstream they should be further apart to allow "accidental" violators to leave the lanes. If the HOV lanes are permanently designated as such, word messages "BUS ONLY" and "CARPOOL ONLY" should be painted on the pavement along with the restricted lane symbol. If the priority operation is part-time, only the symbol is appropriate.

The only apparent need for signalization is at the toll booths where it is common to indicate by green or red signals whether a booth is open. For HOV booths the green can be replaced by enlarged word messages such as "BUSES" and "CARPOOLS."

All of these measures would discourage violations and thus make enforcement easier to accomplish.

Recommendations for Enforcement

General recommendations on enforcement of HOV priority treatments on freeways are presented on page 49 . In regard to exclusive toll plaza lanes, the following specific recommendations are offered.

- AASHTO and MUTCD standards should be strictly adhered to. Some deviation from AASHTO freeway standards are necessarily warranted (e.g. lane starts and lane drops). These deviations should be minimized and geometric features which compromise safety should be avoided.

- Provide special areas, such as a refuge area or shoulder, adjacent to the HOV lanes in order for officers to monitor the HOV lane and conduct the enforcement operations.

- Provide a physical separation, such as a barrier wall or raised curb, between the HOV lanes and general lanes so long as such a barrier does not pose safety hazards itself.

- Where the facility is not metered, the capability of informing toll attendants to halt traffic should be included. This would "clear" the downstream roadway allowing police vehicles to pursue violators and, more importantly, allow emergency vehicles to travel unimpeded.

- If the facility is metered, there should be a manual override which enables the operator to select appropriate signal displays (e.g. all red if there is a downstream incident).

- Line patrols should provide routine enforcement by monitoring the HOV lane operations from stationary positions, preferably adjacent to the lanes. The toll booths are an excellent location for detection, but apprehension is disruptive. When warranted by increasing violation rates, selective enforcement teams should be called in to set up shunt lanes (if refuge areas do not exist) in which to store violators while being ticketed.

CHAPTER FIVE

ENFORCEMENT OF HOV PRIORITY TREATMENT PROJECTS ON ARTERIALS

GENERAL

Enforcement needs, techniques and problems differ greatly between arterial highways and freeways. Arterial highways have an unlimited access operation, and lower total volumes of traffic. In some respects, enforcement is easier on arterial streets and highways because of lower speeds and the availability of detention areas off the roadway. However, in other respects, enforcement of arterial streets and highways is more difficult because of a multiplicity of traffic restrictions to enforce as well as the possibility of being called away for other police functions.

There are several enforcement factors common to HOV priority treatments which are summarized as follows:

(1) Arterial street and highway enforcement is generally accomplished using mobile patrol where the officer has the responsibility for a particular zone or area. This enforcement is generally under the jurisdiction of a local (city or county) agency.

(2) Arterial street and highway enforcement is most heavily burdened during the peak periods mainly because of the higher traffic volumes. It is during these periods that HOV projects require maximum enforcement effort.

(3) Some HOV treatments introduce supplementary traffic restrictions, such as parking and turning restrictions, in order to eliminate potentially hazardous interactions between HOV and general traffic. Oftentimes, these supplementary restrictions place additional demands on the enforcement program.

Arterial Streets and Highways Standards

Current national standards on geometric features for arterial streets are established by AASHTO.[1] This document does not present geometric features or standards specifically applicable to an HOV lane, but it does discuss, in general terms, the use of reserved bus lanes on city streets and arterials. Geometric design elements for an arterial street that could affect roadway safety includes 1) the number of lanes, 2) lane width, 3) curb, 4) median, 5) alignment, 6) design speed, 7) sight distance, 8) roadside hazards, and 9) pedestrian facilities. Table 23 presents the AASHTO standard, if established, for each design element.

Current national standards on traffic control devices for arterial streets are established by FHWA's Manual on Uniform Traffic Control Devices (MUTCD). The MUTCD has established special

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1. American Association of State Highway and Transportation Officials (AASHTO), "A Policy on Geometric Design of Urban Highways and Arterial Streets" (1973 edition), published by AASHTO, Washington, D.C.

pavement markings and signing for preferential lane use control.[2] The pavement marking is an elongated "diamond" symbol formed by white lines. The frequency of the diamond marking is a matter of engineering judgement, but the MUTCD suggests a "spacing as close as 80 feet (24 m) may be appropriate for a city street." The signing regulations include 1) sign shape, color and reflectorization, 2) legend format and sequence, and 3) mounting applications. The types of preferential lane signs include lane-use control signs, advance notification signs, and lane-end signs. The MUTCD suggests that the diamond marking symbol "should be incorporated into the body of the signs as a white symbol on a black background. The sign size, location and spacing are dependent upon the conditions under which it is used, but should be consistently applied." Table 23 and Figure 1 present the MUTCD standard for each traffic control element established for preferential lane control.

Recommendations

There are certain recommendations for enforcement of HOV priority treatment projects which are common to all arterial street and highway applications. These recommendations are:

(1) Enforcement requirements should be included in project planning in the earliest stages and enforcement personnel should be active members of the planning team. The advantages of the early involvement of the enforcement agency in the planning process of an HOV project centers on a) provision of technical advice, b) promotion of cooperative relationships, and c) personnel planning and budgeting. Additional personnel and funds should be made part of the overall project plan if necessary. In order to minimize institutional misunderstands (particularly after implementation), all decisions and agreements should be written and made official by formal memoranda of understanding or similar instruments.

(2) To the extent possible, the HOV priority projects should be designed, constructed and/or modified in conformance to AASHTO and MUTCD standards, as well as other appropriate site-specific requirements.

(3) Officials of the traffic court system should be briefed, prior to the project start-up, regarding the project's operational goals, traffic restrictions, enforcement program and legal basis. Judicial appreciation of the project's merits and constitutional/legal integrity serves well toward developing the proper judicial support for the project. Failure to gain this support may be reflected in judges being too lenient with HOV citations and thereby discourage enforcement efforts.

(4) On projects which establish travel time savings as its operational goal, the HOV restrictions should be imposed only during those time periods when these savings can be achieved. Otherwise, enforcement activity would be required when the project operation is not providing any benefit.

(5) The entire project should be opened at one time (at least by direction). Temporary and/or partial openings often create both safety and enforcement problems which may be greater than those associated with the full system.

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2. United States Department of Transportation (Federal Highway Administration), Manual on Uniform Traffic Control Devices—Official Rulings on Requests, Volume VI, June, 1975, pp. 7-8 and 41-42.

Federal Highway Administration, "Changes in the Manual on Uniform Traffic Control Devices to Provide Pavement Marking and Signs for Preferential Lane Use Control, FHWA Notice N 5160.8, March 17, 1975.

TABLE 23

NATIONAL STANDARDS APPLICABLE TO HOV PRIORITY TREATMENT PROJECTS ON ARTERIAL STREETS

AASHTO DESIGN STANDARDS

1. Number of Lanes: no standard
2. Lane Width: 12 feet
3. Curb and Shoulder: no standard
4. Median: no standard
5. Alignment: no standard
6. Design Speed: 30 to 60 mph
7. Sight Distance: Speed Dependent
8. Roadside Hazards: 20 to 30 feet distance from roadway
9. Pedestrian Facilities: no standard

MUTCD DESIGN STANDARDS

1. Signalization: Lane-use controls on reversible lanes
2. Signing:

	Roadside	Overhead
a. Advanced Warning:	R3-10	R3-13
b. Restricted Lane:	R3-11	R3-14
c. End of HOVL:	R3-12	R3-15

3. Lane Demarcation: Solid or skipped white line[a]
4. Special Markings: Diamond symbol, spaced frequently enough to be in constant view
5. Delineators: Plastic posts (reversible and contraflow lanes only)

Metric Conversion

1 foot = 0.3 m.
1 mile = 1.61 km.

a. There is some question concerning the use of solid lines. While the MUTCD is not explicit, solid lines should be used on HOV lane projects which are either bus-only or 24-hour operations.

(6) Priority sections should be particularly well maintained. The unusual conditions make it imperative to keep the roadway and traffic control devices highly visible.

(7) Enforcement should be supported by extensive public education and publicity of the seriousness of the HOV restrictions. Enforcement agencies commonly agree that a public awareness program, which notifies the public of enforcement activities, increases the effectiveness of the enforcement effort. The public awareness program should be a continuing, on-going program.

(8) Aggressive enforcement should begin immediately to instill a degree of respect of the HOV restrictions. However, the tactics used should initially be "soft" and should minimize traffic disruption. For example, very heavy deployment of troopers in a highly visible fashion would create a favorable enforcement impression. The use of "wave-off," verbal warning (e.g. use of loud speakers), and other non-punitive techniques is preferred to the sudden disruptive effect of massive apprehensions. Publicity of this initial enforcement period should state that enforcement of the HOV restrictions is beginning immediately. The transition to the more formal type of enforcement (issuing citations) should be made in no more than two weeks and preferably one, depending on the anticipated disruption which will occur. Following an initial "crackdown," the aggressiveness and deployment can probably be relaxed.

The remaining sections of this chapter contain detailed information on enforcement requirements and problems regarding the four major types of HOV priority treatments on arterial streets and highways:[3]

- separate facility
- concurrent flow
- contraflow
- signal preemption

Each priority treatment is analyzed by 1) details of the HOV projects investigated, 2) operational results of the HOV projects, 3) enforcement characteristics of the HOV projects, 4) geometric standards related to enforcement, 5) traffic control standards related to enforcement, and 6) recommendations for enforcement.

SEPARATE FACILITY

Separate facilities on an arterial street system are commonly referred to as "transitways" because the only type of vehicle that is generally permitted to travel on such a facility is the transit coach. There are two types of transitways, each serving a different objective:

(1) A separate facility serving as a major transit collection/distribution route. These facilities tend to be located in the central business districts in order to provide a high level of transit accessibility to heavily concentrated retail and business districts. Commonly associated

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3. For a complete evaluation of safety problems associated with HOV priority treatments, see Beiswenger, Hoch and Associates and Transportation Research Center, Safety Evaluation of Priority Techniques for High Occupancy Vehicles, Federal Highway Administration, DOT-FH-11-9182, 1979.

with this transitway is some type of pedestrian mall and other aesthetic features. The benefits of this type of transitway are transit accessibility and separation of different classes of vehicles.

(2) A separate facility serving the line-haul portion of transit service. Because of this function, these facilities tend to connect the CBD with the outlying areas. The benefits associated with this type of transitway would be the more traditional HOV objectives of travel time savings and increased total person through-put.

This report will examine the separate facility serving as a major transit collection/distribution route, because this is the predominant type of separate facility on an arterial street. Such a transitway is commonly referred to as a transit mall. Transit malls are generally linear and range in length anywhere from several blocks to one mile. Sidewalks are widened and other pedestrian amenities are included. Vehicular (bus) entrance and exit to the transit mall generally occurs at the two terminal points of the project. Cross traffic across the transit mall is generally permitted but is not allowed to access the facility. Transit malls tend to be easily enforced.

Details of Projects Investigated

Because enforcement of a separate facility is relatively easy, only the Nicollet Mall in Minneapolis, Minnesota, was investigated in detail. A description of this transit mall is given below and in Figure 15.

Nicollet Mall is an eight block section—0.6 mile (1.0 km)—of Nicollet Avenue in the core of Minneapolis' retail and business district. In 1967, the 80 feet (24 m) of right-of-way along Nicollet Avenue, which formerly contained four lanes of traffic, two parking aisles and 30 feet (9 m) of sidewalk, was altered into a 24-feet (7.2 m) bi-directional transit-way and 56 feet (16.8 m) of sidewalks. The amount of sidewalk available on each side of the transit-way varies as the roadway meanders back and forth at a rate of one cycle per block. Between the two terminal locations, Nicollet Mall traverses seven streets. Vehicular access to the mall is not permitted at these intermediate intersections, and all vehicles using the mall must access and egress the facility at its two terminal points. The transit mall is served by numerous local transit routes and a downtown mini-bus circulation system. Other vehicles that may use the transit mall include taxis (on-call), emergency vehicles and bicycles. Numerous aesthetic features were incorporated into the mall including trees and shrubs and the beautification of storefronts, street lights, traffic signs, bus stop shelters and phone booths.

Table 23 presents the national standards applicable to HOV priority treatments on arterial streets and highways. The Nicollet Mall is consistent with AASHTO standards. The geometrics are important in two locations—the terminal points and cross street intersections—which can impact safety and enforcement of the operations.

At one terminal point, both the mall and Nicollet Avenue terminate thereby simplifying the terminal geometrics to a standard T-intersection requiring no special geometric features. The geometrics at the other terminal point are more complicated since traffic on Nicollet Avenue heading toward the mall must be channeled into mall and non-mall traffic lanes. This situation is simplified by the cross street being one-way thereby reducing the number of different-turning movements. The separation of traffic into mall and non-mall lanes is accomplished by an island channeling the traffic into 1) a left-hand lane which is on an alignment leading directly into the mall; or 2) a right-hand lane which forces traffic to

turn right onto the cross street.

Cross street traffic has not been removed from Nicollet Mall, resulting in heavy pedestrian movements from the mall conflicting with heavy vehicular cross-street downtown flows. This conflict is minimized by 1) all cross streets being one-way flows, and 2) a city ordinance prohibiting all turns onto or off of the Nicollet Mall at intermediate intersections. The non-existence of any appreciable roadway curvature at the intersections of the mall and the cross streets causes any potential turns onto or off the mall to be very awkward. The radius of this curvature is so tight that a passenger car would be unable to negotiate a right hand curb-to-curb turn at any speed without encroaching on the adjacent lanes (based on the AASHTO 24-feet* minimum turning path for a passenger car). A bus would be unable to make a right-hand turn from the two lanes nearest the curb without running over the sidewalk. These geometric features lend themselves very favorably to the enforcement effort. Additionally, the wider sidewalks of the mall provide for greater pedestrian holding capacity at the intersections resulting in more efficient pedestrian crossing movements.

Estimates currently show the mall to be operating at 80 percent capacity, and there seems to be widespread sentiment among the mall's active participants that no more buses should operate on the mall. The primary motive behind limiting the number of buses on the mall is not to enhance the transit-way's operation, but to avoid overwhelming the pedestrian mode. Inherent in this motive is a concern for pedestrian safety, due to highly uncontrolled and spontaneous pedestrian movements across the transit-way.

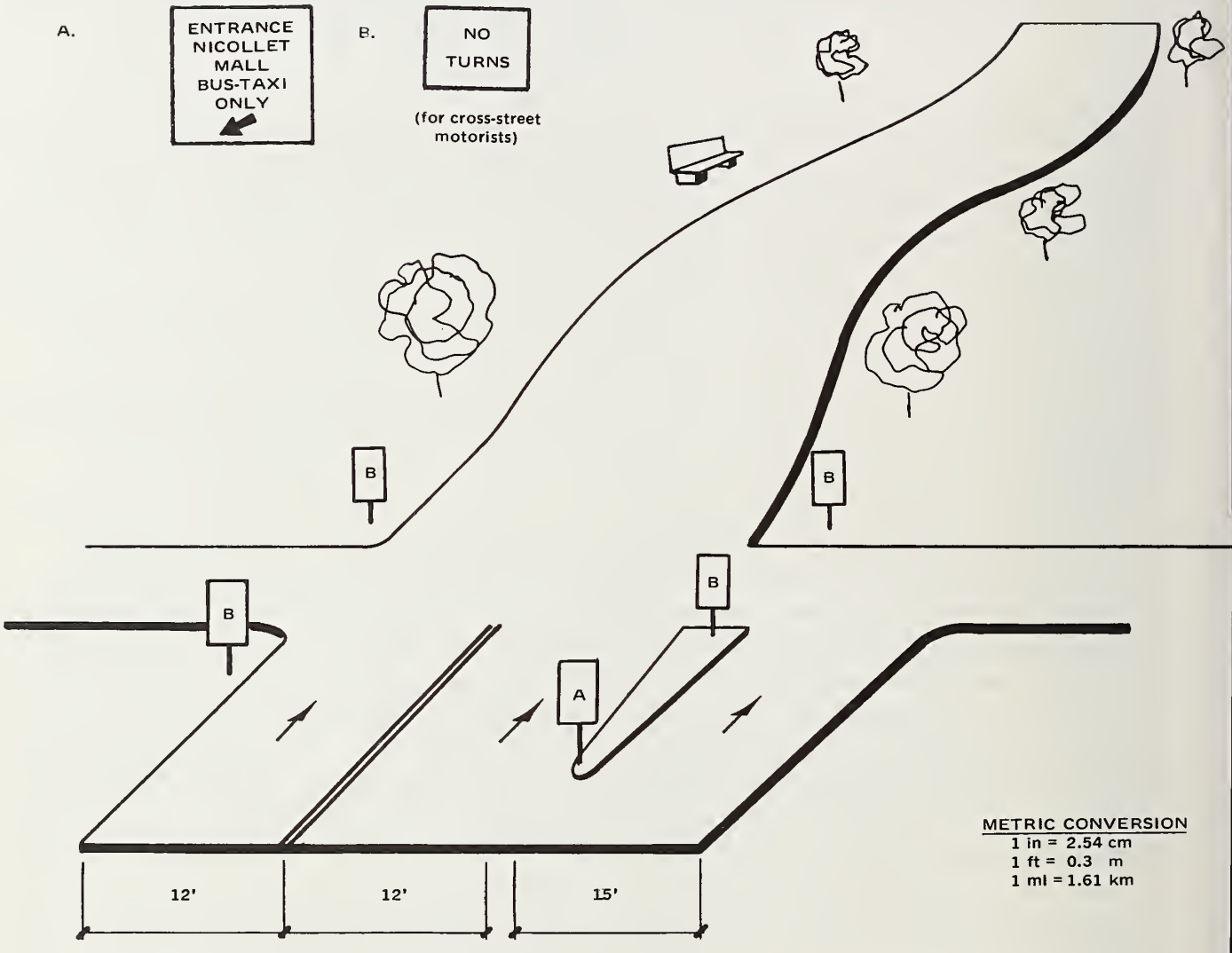
Minimal signing has been incorporated into the Nicollet Mall mainly for aesthetic reasons and because there are minimal driver information requirements. The transit-way does not have any HOV signing or markings. Custom black on white information signs displayed at the two terminals provide the motorist with specific instructions concerning the transit-way's vehicle restrictions and proper lane usage. Other than the two terminal points, the only sign displayed in conjunction with the mall is a "NO TURNS" sign facing cross street traffic. This sign is recessed into an aesthetically designed traffic signal pole. Because of this aesthetic effort, the sign is relatively non-conspicuous and does not conform to MUTCD standards. It is the belief of one patrolman on Nicollet Mall that the "no turns" sign is inadequate and is not a legally-acceptable basis for issuing citations. No data was available to substantiate or refute this from the local judiciary.

The Nicollet Mall transit-way does not utilize 1) longitudinal markings to separate the two opposing traffic lanes, 2) intersection stop lines for the transit-way, and 3) crosswalk markings for either the transit-way or the cross streets. The lack of these traffic control markings does not specifically violate mandatory standards established by the MUTCD. However, the design does violate MUTCD "advisory" standards as stated:

- "Stop lines should be used . . . . where it is important to indicate the point, behind which vehicles are required to stop, in compliance with a STOP sign, traffic signal, officers' directions, or other legal requirement."
- "Crosswalks should be marked at all intersections where there is substantial conflict between vehicle and pedestrian movements."

* 24 feet = 7.3 meters

FIGURE 15
NICOLLET MALL, MINNEAPOLIS, MINNESOTA



AASHTO DESIGN FACTORS

ALIGNMENT: curvilinear
VERTICAL SIGHT DISTANCE: good
POSTED SPEED: none
ROADSIDE HAZARDS: structures within several feet of roadway

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: none
ADVANCED WARNING SIGNS: none
RESTRICTED LANE SIGNS: none
END OF HOVL SIGNS: none
DIAMOND SYMBOL: none
HOVL DELINEATION: none

NICOLLET MALL, MINNEAPOLIS, MINNESOTA

Operational Results

The extent of the enforcement requirements for an HOV project is dependent in part to the operational effectiveness of the project. The Metropolitan Transit Commission (MTC) operates the overwhelming majority of buses on the transit-way. Over 600 buses use the mall daily with afternoon peak-hour volumes totalling 60 buses per hour. The other vehicles permitted on the transit-way (including taxis, bicycles, emergency vehicles) do not create any operational problems for the bus movements.

The lack of pedestrian control has resulted in the transit operator being made primarily responsible for minimizing pedestrian conflicts by driving at low speeds and extending substantial driving courtesy. As evidence of the low speeds (average running speed is 10-15 mph (16-24 kph), MTC contends that running times on Nicollet Avenue have increased by two minutes since the initiation of the mall. The low bus speeds do not conflict with Nicollet Mall's function in the overall transit strategy. The mall serves as a major distribution/collection point. Project objectives do not include higher speeds and reduced travel times.

Enforcement Characteristics

Violations of the transit-way restrictions are virtually non-existent and no enforcement effort is made in this regard. Minneapolis Police follow the procedure of redirecting any illegal vehicle from the transit-way. Generally the rare illegal vehicle is a motorist from outisde of Minneapolis who inadvertently entered the transit-way. A lack of violations is due to: 1) a private automobile would be very conspicuous and easy to detect, apprehend and cite; 2) a violator would not likely gain any travel time savings due to low bus travel speeds; and 3) the entry/exit points to the transit-way are located only at the terminal locations because of non-turn radii of the cross streets. Minneapolis police rarely issue a citation for illegal use of the transit-way. In order to do so, the motorist would have to be a repeat violator.

The primary objective of the Minneapolis Police Department's traffic control efforts on the Nicollet Mall has been pedestrian safety. In order to minimize the pedestrian/bus conflicts, an elaborate pedestrian crossing system of the transit-way was developed and installed. This system involved mid-block pedestrian signals that were controlled by detectors located one block away that sensed the passage of an approaching bus. Mid-block pedestrian crossing of the transit-way would be permitted only when there is no approaching bus. Because the system was generally ignored by the pedestrian, it has since been removed.

Accompanying the abandonment of the pedestrian control system, there was a general abandonment of all enforcement efforts concerning "jaywalking" violations on the mall. The volume of the pedestrian traffic and the nature of the mall's business created a great number of legal and illegal pedestrian crossing maneuvers. Minneapolis Police believed any reasonable attempt to curb the jaywalking would be futile and cause negative feelings toward the police.

Minneapolis police manpower assignments on the mall consist of two foot patrolmen stationed at the busiest intersection of Nicollet Mall. This intersection has the largest concentration of pedestrians and the highest cross street volume. Occasionally, an additional patrolman is assigned to the mall with no specific locational assignment. The sole function of these patrolmen is to minimize pedestrian

and cross-street traffic conflicts by directing the traffic in coordination with the existing signal system. These officers also handle numerous questions from pedestrians. The patrolmen working this Nicollet Mall intersection are greatly concerned about a tragic accident occurring from a pedestrian inadvertently stepping into traffic because of 1) impaired health, or 2) lack of concentration due to the mall's surroundings. The patrolmen believe that this situation would occur more frequently without their presence.

Police vehicles in the vicinity of the mall often cruise the transit-way during the course of their assignment. However, no mobile patrol is given a specific assignment to cover the mall and their presence on the transit-way is not part of the mall's enforcement strategy. A high degree of enforcement visibility is provided to the mall from this irregular modus operandi.

Geometric Standards Related to Enforcement

The section "Details of Projects Investigated" elaborated on the interrelationship between the geometrics of Nicollet Mall's transit-way and the transit-way's operation regarding enforcement and safety.

Generally, the separate facility is established by restricting, for the desired length, an arterial street that previously handled through traffic. For this treatment, the general traffic on the arterial and approaching transit-way can be channeled and guided from the street much in the manner of a non-through leg of a T-intersection. Terminal treatments for a separate facility can vary considerably because the treatments are site specific. Access and egress to the separate facility most often occurs only through the facility's terminal points even though the facility will most likely traverse at-grade intersections with cross streets. The access and egress is controlled at the cross-street intersections through both traffic restrictions and possibly supportive geometrics such as a low curvature radius not allowing for adequate turning path for a passenger car. By controlling the access and egress of the facility, the safety and enforcement aspects of the facility can be enhanced.

Traffic Control Related to Enforcement

The section "Details of Projects Investigated" elaborated on the interrelationship between the traffic control elements of the Nicollet Mall's transit-way and the transit-way's operation regarding enforcement and safety.

Traffic control devices used in conjunction with a separate facility may include 1) signing, 2) pavement markings, and 3) delineators. Such traffic devices perform the following functions:

- delineate between opposite flows of traffic
- designate the separate facility and its associated restrictions regarding turning and parking
- provide advanced information and warning to motorists

Traffic control devices applies to the separate facility treatment restrictions are most needed in the vicinity of the terminal areas and other possible access points. This is the location where the general traffic and separate facility need to be effectively and safety segregated. A variety of localized regulatory signs and markings are necessary to 1) inform motorists of the separate facility's restrictions, and 2)

channel the different classes of traffic into or away from the separate facility.

As previously mentioned, a separate facility is oftentimes associated with a pedestrian mall. In order to make the mall and transitway more aesthetically pleasing, the proper use of traffic control devices has been compromised on several projects. This compromise includes such matters as the placement of non-standard signs in a non-conspicuous place and elimination of pavement markings and cross-walk markings. Police may believe that the use of out-of-the-way, non-standard signs does not provide a legally acceptable basis for the issuance of citations. The elimination of pavement markings and cross lines may violate MUTCD "advisory" standards.

Recommendations for Enforcement

General recommendations for enforcement of HOV priority treatments on arterial streets and highways are presented on page 117. In regard to a separate facility transit-way, the following specific recommendations are offered to improve the general operation.

- Appropriate pedestrian controls should be instituted if pedestrain crossing is considered to be a safety problem. These controls include pedestrian cross-walks, pedestrian signals and strict enforcement of "jay-walking." The pedestrian cross-walks and signals may be located at intersection and mid-block locations. The Nicollet Mall experience demonstrated that pedestrians will not adhere to mid-block signals across roadway widths as low as 24 feet (7.2 m). If strict pedestrian control is essential, restraining rails separating the sidewalk and roadway must be employed.

- Procedures regarding bus operations on the transit-way should include: 1) reduced bus speeds, and 2) increased driver awareness and courtesy. A reduced bus speed should not detract from the bus operations because the prime advantage of the transit-way is its accessibility and that is not affected.

- Cross streets across the transit-way should be eliminated whenever possible. When the elimination of cross streets is impossible, the turning movements between the transit-way and the cross streets should be restricted. Traffic signals and signs should be standard and easily visible to the motorists. A one-way cross street is preferred to a two-way cross street because of the fewer potential conflicts and traffic operational requirements.

- It is important that terminal areas and any other access areas be well signed and marked and the traffic appropriately channeled. The signing should conform to MUTCD standards.

- The use of routine zone enforcement or routine line enforcement in either mobile of pedestrian modes should be satisfactory for HOV enforcement purposes.

CONCURRENT LANE

Concurrent flow priority applications on arterial highways involve reservation of either the curbside lane or the median lane for high-occupancy vehicles. These applications have differing operational objectives and somewhat differing enforcement requirements.

Curbside lanes have historically been installed to provide better transit circulation in the CBD and/or to improve downtown traffic flow through the segregation of buses and autos. A second objective

may be to provide a travel time improvement (not advantage) for buses. Curbside lanes are commonly associated with local bus service that makes frequent stops at assigned locations (bus stops) for passenger loading and unloading. The concurrent flow curb HOV lane can be either a 24-hour or peak-period operation over a distance that ranges from several city blocks to several miles. Taxi-cabs, other vehicles loading and unloading passengers, right-turning vehicles, motorcycles and bicycles may also be permitted to travel in the curb HOV lane. Enforcement requirements on the curbside concurrent lanes address illegal stopping, parking or ineligible vehicular travel in this lane.

Median lanes are generally intended to provide high-occupancy vehicles with travel time advantages by bypassing traffic congestion in the general traffic lanes. Median lanes are commonly associated with express bus service operating in a through or express mode. The concurrent flow median lane operates generally during the peak-period in the peak direction, over a project length of several miles. Carpools may also be permitted to travel in the concurrent flow median HOV lane; however, this inclusion usually intensifies the need for enforcement. Enforcement requirements address the illegal travel in the lane as well as possible illegal turning movements across the median HOV lane.

Details of Projects Investigated

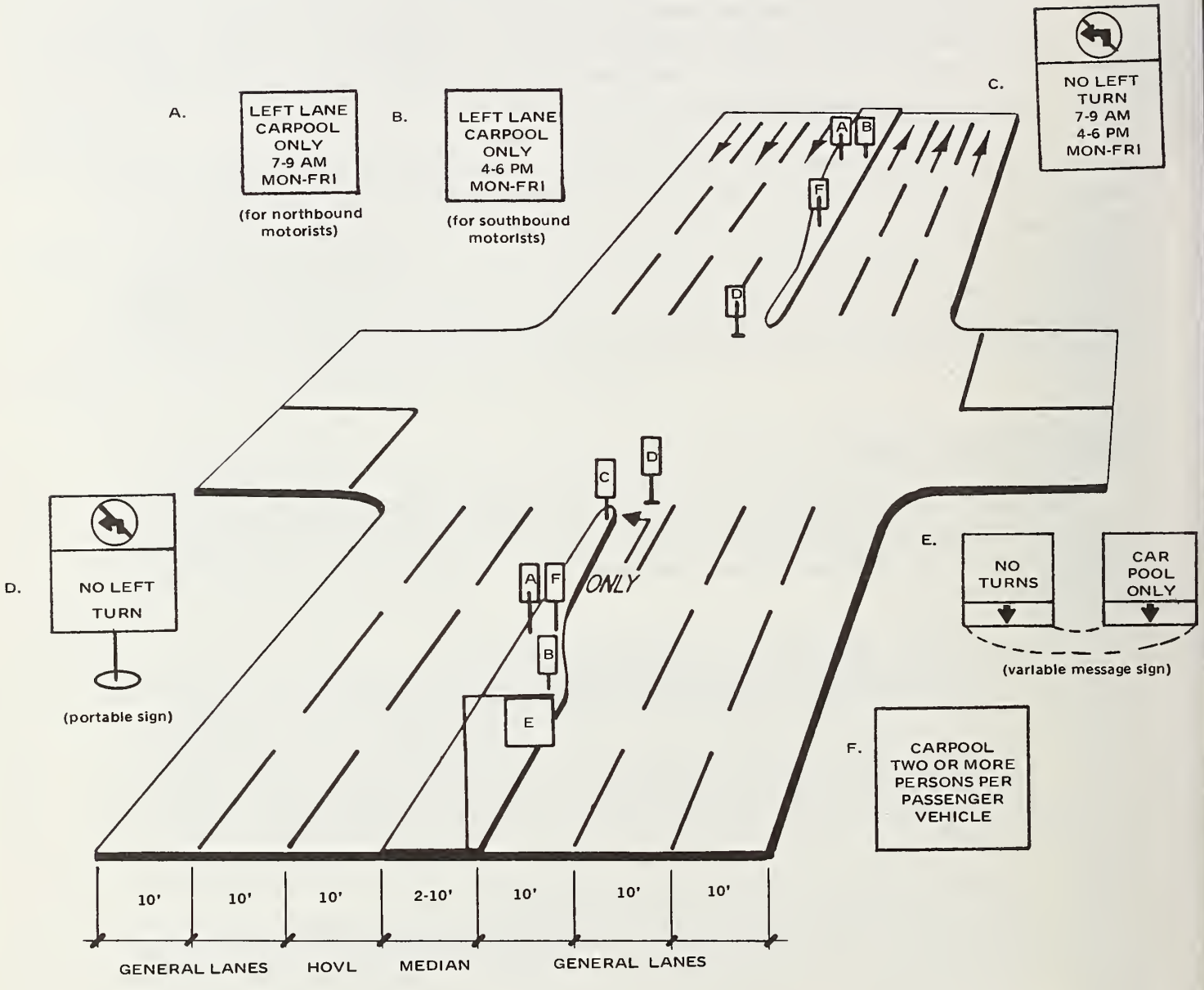
Enforcement of concurrent flow HOV lanes on arterial streets and highways can be difficult and an important component of the project's operation. Three concurrent flow HOV lane projects (one median and two curbside applications) were investigated in detail. Project descriptions are given below and in Figures 16 to 18.

- U.S. 1/South Dixie Highway, Miami, Florida (Figure 16)
  This project included a concurrent flow median carpool lane, a contraflow median bus lane and signalization improvements on a 5.5 mile (8.9 km) segment of South Dixie Highway (U.S. 1). A carpool is defined here as a vehicle carrying two or more persons. Left turns across the median HOV lane are prohibited. The HOV lanes operate in the peak direction during the peak periods of 7-9 AM and 4-6 PM. The project commenced in July, 1974. In April, 1976, express "Blue Dash" buses were transferred into the concurrent flow median carpool lane.

- Washington, D.C., CBD, Washington, D.C. (Figure 17)
  This project has 28 lane-miles of curb lanes on 18 arterial streets or service roads. Some streets have a bus lane in each direction, while others have the priority treatment in only one direction. The length of the curb lane ranges from 0.1 mile (0.2 km) (one city block) to 3.6 miles (5.8 km). The curb bus lanes are generally in effect for both peak periods (7:00-9:00 AM and 4:00-6:00 PM) but there are exceptions to this including a 24-hour operation and several peak period/peak direction-only operations. Implementation of the curb bus lanes occurred over a period of 12 years beginning in 1962. The objective of the project is to provide for more efficient circulation of buses in the downtown area and also to reduce bus travel times on radial arterials. During the time of bus lane operation, taxi-cabs, other vehicles loading and unloading passengers, right-turning vehicles, motorcycles, and bicycles are also permitted to use the lane.

- Elm/Commerce Streets, Dallas, Texas (Figure 18)
  Elm and Commerce Streets comprise a one-way pair of arterials in the core of the Dallas CBD. Between the hours of 7-9 AM and 4:30-6:00 PM weekdays, the right-hand curb lane for a 0.3 mile (0.5 km) section of Elm Street and a 0.4 mile (0.6 km) section of Commerce Street is reserved for buses and right-turning vehicles and the other four lanes

FIGURE 16
US 1/SOUTH DIXIE HIGHWAY (CONCURRENT LANE), MIAMI, FLORIDA



METRIC CONVERSION
1 in = 2.54 cm
1 ft = 0.3 m
1 mi = 1.61 km

AASHTO DESIGN FACTORS

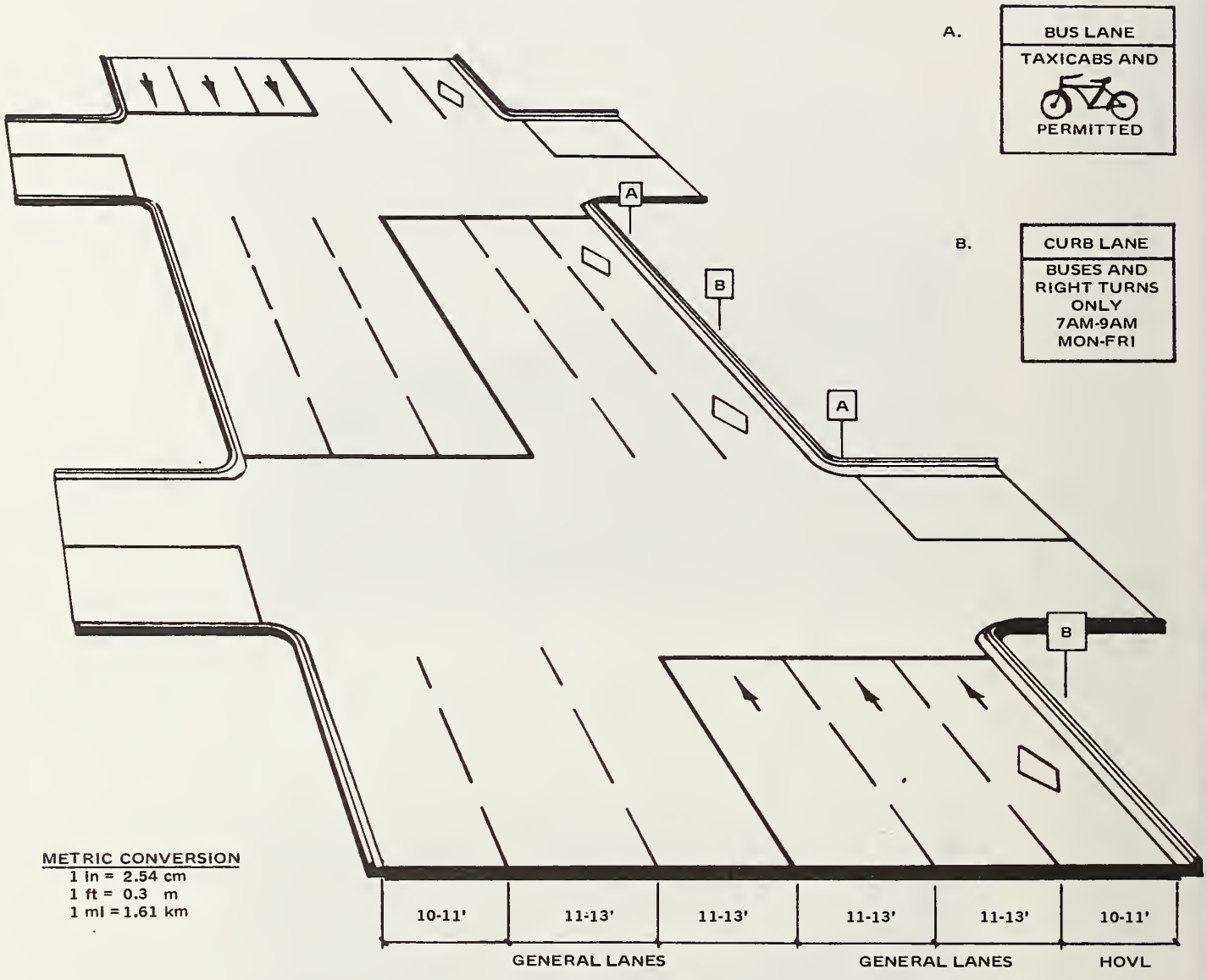
ALIGNMENT: linear
VERTICAL SIGHT DISTANCE: adequate to poor
POSTED SPEED: 35 mph
ROADSIDE HAZARDS: poles within several feet of roadway

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: none
ADVANCED WARNING SIGNS: non-standard
RESTRICTED LANE SIGNS: non-standard
END OF HOVL SIGNS: none
DIAMOND SYMBOL: none
HOVL DELINEATION: skip white marking

U.S. 1/SOUTH DIXIE HIGHWAY (CONCURRENT LANE), MIAMI, FLORIDA

FIGURE 17
WASHINGTON, D.C. CBD STREETS



AASHTO DESIGN FACTORS

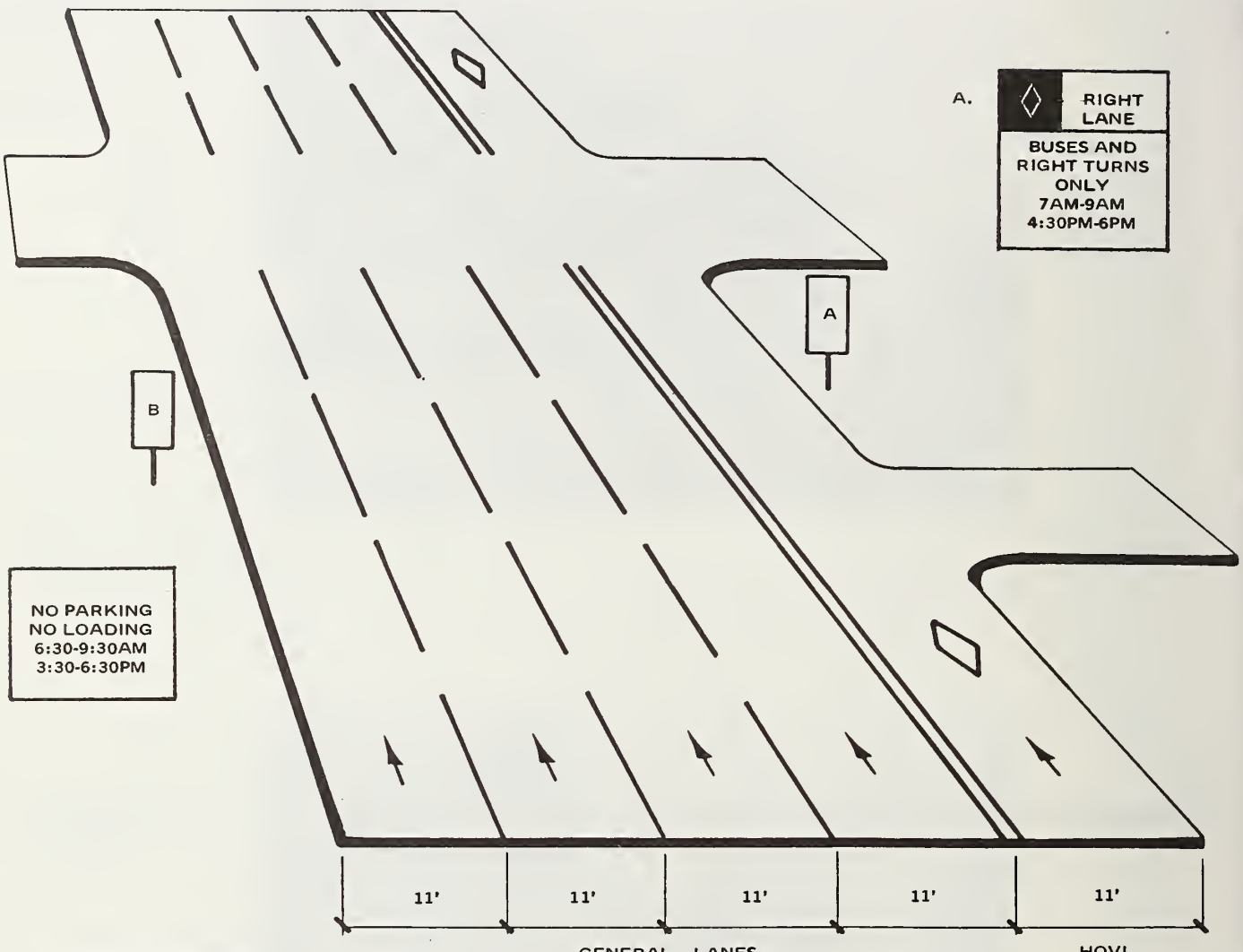
ALIGNMENT: varies
VERTICAL SIGHT DISTANCE: adequate to good
POSTED SPEED: varies
ROADSIDE HAZARDS: poles within several feet of roadway

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: none
ADVANCED WARNING SIGNS: standard
RESTRICTED LANE SIGNS: standard
END OF HOVL SIGNS: standard
DIAMOND SYMBOL: standard
HOVL DELINEATION: none

WASHINGTON, D.C. CBD STREETS

FIGURE 18
ELM/COMMERCE STREETS, DALLAS, TEXAS



METRIC CONVERSION
1 in = 2.54 cm
1 ft = 0.3 m
1 mi = 1.61 km

AASHTO DESIGN FACTORS

ALIGNMENT: linear
VERTICAL SIGHT DISTANCE: good
POSTED SPEED: 25 mph
ROADSIDE HAZARDS: poles within several feet of roadway

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: none
ADVANCED WARNING SIGNS: standard
RESTRICTED LANE SIGNS: standard
END OF HOVL SIGNS: standard
DIAMOND SYMBOL: standard
HOVL DELINEATION: double solid white marking

ELM/COMMERCE STREETS, DALLAS, TEXAS

handle general traffic. The separation of traffic provides the buses with an improvement (not advantage) in travel time. The system has operated since 1957.

Table 23 presents the national standards applicable to HOV priority treatments on arterial streets and highways.

The U.S. 1/South Dixie project is deficient in lane widths, proximity of roadside hazards, and occasionally, sight distance. The project utilizes non-standard restricted lane signing located overhead as a changeable message sign and in the median as a static sign. The diamond pavement marking is not used. The project initially used polyvinyl chloride (PVC) safety posts at a 40-feet (12 m) spacing to differentiate the HOV lane from the general traffic lanes. The posts were later eliminated, without a noticeable increase in the violation rate, because of a potential safety hazard (i.e., motorists weaving erratically to avoid hitting the posts or maneuvering illegally around the posts).

The Washington, D. C. project is deficient on various streets in lane width and proximity or roadside hazards. Otherwise, the project does closely conform to the MUTCD requirements regarding preferential lane signing and marking with one exception. Prior to the establishment of MUTCD standards for preferential lane-use control, the Washington, D. C. project utilized two signs for the curb bus lane. One sign restricted the curb lane to buses and right-turning vehicles during the stated hours. The other sign identified the other vehicles—taxi-cabs, motorbikes and bicycles—that are also permitted to travel in the restricted curb lane. These two old signs are being replaced (the process is not yet fully completed) by one sign that conforms to the MUTCD standard. This new sign only restricts the curb lane to buses and right-turning vehicles during the stated hours. The eligibility of the other special vehicles to the curb lane is not being signed but only publicized. This development is not consistent with the MUTCD guidelines of indicating fully the proper use of the lanes.

The Elm/Commerce Streets project is deficient in lane width and proximity of roadside hazards. The project does closely conform to the MUTCD requirements regarding preferential lane signing including advance warning, lane control and end-of-lane signing. The diamond pavement marking is not used and the delineation between the curb lane and other lanes is a double white solid line.

The geometric deficiencies regarding lane width and proximity of roadside hazards is quite common for urban areas and especially for downtown areas where available right-of-way for streets and highways is a scarce commodity. These deficiencies do not affect enforcement operations or the tendency to violate the HOV lane.

Operational Results

The extent of the enforcement requirements for an HOV project is dependent in part on the operational characteristics of the project. The operational results of each project are presented in Table 24. The results presented for the Washington, D. C. project represent Connecticut Avenue only since overall data on the project was non-existent. From this table, several of the more significant results are:

- Each project illustrates the potential efficiency of HOV operations. On the U.S. 1/South Dixie Highway project, the HOV lane carries 41 percent of the persons in 24 percent of

TABLE 24

OPERATING CHARACTERISTICS ON CONCURRENT FLOW HOV LANE PROJECTS

VARIABLE	UNIT	PROJECT/CONDITION			
		U.S. 1/S. Dixie Highway[a]		Washington, D.C. Project[b]	Elm/Commerce Streets[c]
		Before	Bus/3 ppv Carpool	Bus-Only	Bus-Only
Critical Peak Period	—	7 - 9 AM; 4 - 6 PM	7 - 9 AM; 4 - 6 PM	6:30 - 9:30 AM	8 - 9 AM
Length of HOV Lane	Miles	—	5.5	3.6	0.3
Total Peak Directional Lanes	Lanes	3	3	4	5
Number of HOV Lanes	Lanes	—	1	1	1
Volume - All Lanes	Vehicles	10,664	11,709	4,352	1,382
Volume - HOV Lanes	Vehicles	—	2,834	141	215
Volume - HOV Lanes (bus only)	Vehicles	—	51	141	61
HOV Lanes/Total Volume	%	—	24.2	3.2	15.6
Auto Occupancy - All Lanes	PPV	1.25	1.22	1.59	na
Auto Occupancy - HOV Lanes	PPV	—	1.71	—	—
Person Throughput - All Lanes	Persons	13,330	16,232	13,121	4,500(est.)
Person Throughput - HOV Lanes	Persons	—	6,716	6,438	2,400(est.)
HOV Lanes/Total Throughput	%	—	41.4	49.1	54.2
Speed - General Lanes	MPH	19.4	18.5	24	na
Speed - HOV Lanes	MPH	—	25.7	10-13	na
Travel Time - General Lanes	Minutes	17.9	17.8	9	na
Travel Time - HOV Lane	Minutes	—	12.8	16-22	na
Accident Rate	Acc./mvm	5.2	8.3	2.3	na

Metric Conversion

1 mile = 1.61 kilometers

a. Before data are for three hour peak periods (6-9 AM and 4-7 PM) that is reduced to two hour peak periods by assuming uniform hourly rates.
b. Data represent Connecticut Avenue.
c. Data represent Commerce Street.

TABLE 25

ENFORCEMENT CHARACTERISTICS ON CONCURRENT FLOW HOV LANE PROJECTS

VARIABLE	U.S. 1/South Dixie Highway	Washington, D.C. Project	Elm/Commerce Streets	
	Bus/3 ppv Carpool	Bus-Only	Bus-Only	
	Combined Peaks	AM	AM	PM
HOV Lane Volume	2,834	141	215	137
Number of Violators	156	NA	25	24
Violation Rate (%)	5.5	NA	11.6	17.5
Number of Citations	16.5	NA	NA	NA
Apprehension Rate (%)	10.6	NA	0-1	0-1

the vehicles. On the Washington, D.C. curb bus lanes project (Connecticut Avenue), the HOV lane carries 49 percent of the persons in 3 percent of the vehicles. On the Elm/ Commerce Street curb bus lanes project (Commerce Street), the HOV lane carries an estimated 54 percent of the persons in 16 percent of the vehicles.

- A comparison of the bus speeds on each project shows that the curb HOV lane is associated with local bus service and the median HOV lane is associated with express bus service. For the Washington, D. C. CBD project, local bus service traveled at 10 mph (16 kph) whereas express bus service traveled only slightly higher at 13 mph (21 kph). This compares to the automobile speed of 24 mph (39 kph) on the facility. The Elm/Commerce Streets project experiences similar travel conditions, even though data does not exist to document it. The U.S. 1/South Dixie Highway project shows a travel speed of 26 mph (42 kph) in the median HOV lane as compared to 19 mph (31 kph) in the general travel lanes.

- Travel times for both the Washington CBD project and Elm/Commerce Streets projects improved from the "before" condition for the local bus travel. Whereas, the bus travel times did improve, the travel speeds were somewhat less than that experienced in the general lanes. This improvement in bus travel time and operating speed is due to the separation of the bus and automobile traffic. Because of the higher travel speeds for the U.S. 1/South Dixie Highway project, persons traveling in the HOV lane experience a travel time savings of five minutes over general lane travel for the 5.5 mile (8.9 km) section.

- The accident rate increased from the "before" to the "after" condition for the U.S. 1/ South Dixie Highway project. The "before" accident rate is 5.2 accidents per million vehicle miles (3.2 accidents/mvk), whereas the "after" accident rate is 8.3 accidents per million vehicle miles (5.1 accidents/mvk). A "before" versus "after" comparison is not possible on the other two projects because of a lack of available data.

Enforcement Characteristics

Chapter 3 presented details on HOV projects related to 1) the enforcement program, 2) the enforcement problems and deficiencies, and 3) the enforcement program's performance. These enforcement elements are summarized here for the three concurrent flow HOV projects.

- U.S. 1/South Dixie Highway, Miami, Florida
  The enforcement of this project is divided between two agencies—the Dade County and City of Miami police departments. The project deploys special enforcement consisting of stationary patrols located in the left-turn bays, which are not in use because of left-turn restrictions. Violators of the HOV lane are waved into the left-turn bay which is used for a detention area in order to issue the citation. On any day, six to ten officers are deployed. Enforcement efforts are directed toward the enforcement of the left-turn restrictions as well as the illegal use of the HOV lane. This special enforcement required a special enforcement budget funded by the project management agency (Dade County Office of Transportation Administration) and not the enforcement agencies.

- Washington CBD Curb Bus Lanes, Washington, D.C.
  The Metropolitan Police Department enforces the bus-only (with exceptions) restriction of the curb bus lanes using routine enforcement because a lack of enforcement funds does not allow for any specialized enforcement. The routine enforcement program consists of a mobile patrol having one enforcement vehicle per 36 square block area. Besides illegal traveling in the HOV lane, enforcement is also directed toward illegal parking in the curb lane. Special enforcement is used for illegal parking on several streets whereby a tow truck removes the parked vehicles.

- Elm/Commerce Streets, Dallas, Texas

  The Dallas Police Department enforces the curb bus lanes using routine enforcement because the project has what is considered an acceptable violation rate with this level of enforcement. The routine enforcement program consists of two to three officers on foot patrol. Officers wave off a vehicle illegally traveling in the curb lane. This violation is considered low priority by the officers. Besides illegal traveling in the HOV lane, enforcement is also directed toward no parking and no standing restrictions in the curb lane.

Violation data are presented in Table 25. From this table, several of the more significant results are:

- For the two projects having available data, the violation rate was lower on the U.S. 1/South Dixie Highway project where the rate is 5 percent. This is most likely due to the project's extensive special enforcement campaign. This violation rate does not reflect violations of the left-turn restrictions. On the Elm/Commerce Streets project, the violation rate ranged between 12 and 18 percent with little or no enforcement. Approximately one-third of the violators were illegally parked or stopped vehicles in the lane. There is no violation rate data available on the Washington CBD curb bus lanes project.

- The special enforcement program on the U.S. 1/South Dixie Highway project apprehended approximately 11 percent of the violators. In the early stages of this project, an average of 50 HOV citations were issued daily. On the Elm/Commerce Streets project, very few citations are issued.

In summary, concurrent lane projects can be operated effectively with reasonably few violations, however, this may require a special enforcement program. Without special enforcement, the number of violations may interfere with the operations of the HOV lane. The next sections explore some geometric and traffic control conditions that may affect the violation rate.

Geometric Standards Related to Enforcement

The officials of the U.S. 1/South Dixie Highway project believes that the enforcement effort is greatly aided by the existence of a physical median having numerous left-turn bays. Because left-turns are prohibited during project operating hours, the left-turn bays are used for enforcement purposes. These left-turn bays provide 1) a vantage point to observe the HOV lane, and 2) a refuge area adjacent to the HOV lane where apprehension and the issuance of the citation can occur.

In the absence of any suitable vantage point/refuge area in the median, the enforcement procedure would be confined to moving patrols which can be disruptive, time-consuming and relatively inefficient. The officer, in the absence of any passing lanes, would be forced to perform erratic maneuvers through congested traffic. The problem associated with pursuing violators to the right shoulder or off the roadway, is clearly a function of the number of lanes to be traversed, the traffic volumes and speeds in those lanes. The problem is further complicated by the fact that two vehicles are making the maneuver rather than one. Public support of the enforcement effort may play an important role in this technique. If support is high, general lane traffic will tend to yield to the police car which can "run interference" for the violator. On the other hand, if the public does not support the enforcement (i.e. generally opposes the restrictions), it may be very difficult to locate adequate gaps for the weaving maneuver. Because of the need for maneuverability with this technique, a motorcycle is better suited for the enforcement. However, a motorcycle tends to compromise the personal safety of the officer.

The confinement of curbside concurrent HOV lanes to CBD areas limits the extent to which an effective enforcement program can be conducted. There rarely exists any vantage point from which the officer can survey priority lane operation while keeping out of view. With CBD roadway geometrics generally incorporating every available roadway space for vehicular movements, the citation procedure must necessarily obstruct a lane of traffic. Possibly, the violators can be ticketed on a cross street. Enforcement procedures are limited to either random mobile patrol or foot patrol. Mobile patrol can be very conspicuous and unable to effectively concentrate on isolated problem locations. Foot patrols often have difficulty in apprehending violators. As a result of geometrically induced enforcement deficiencies, enforcement agencies could be unable to effectively deal with certain curbside enforcement problems without the dedication of special manpower contingents. Problems manifest particularly in instances where the concurrent lane is reserved from space previously used for stopping and parking and especially during inclement weather.

Traffic Control Related to Enforcement

Traffic control devices are the legal basis for enforcement and therefore have great importance. Since concurrent lanes are continuously accessible, the nature of the restriction should be clearly stated ahead of, and within, the priority treatment section to assure that unwary motorists do not mistakenly use the lane. In addition, the stronger the force of the traffic control devices, the less likely there will be unknowing violators. The various classes of traffic control devices include: signalization, signing, pavement markings and delineators.

Signing is the only legal basis for issuing citations for HOV violations and therefore must be very clear to the public. Since the HOV lanes are likely to be continuously accessible, signing must be frequent enough to alert new arrivals on the roadway and to continuously remind through traffic of the continuation of the restrictions. "End-of-HOV lane" signing is also important to enforcement, particularly if the lane continues as a general-use lane. Such signing is necessary in order to establish the location where use of the HOV lane is available to all motorists and not just HOV vehicles. Signing can be aided by pavement markings as specified in the MUTCD.

There is no requirement for physical delineation on continuously accessible concurrent HOV lanes. Wider skip lines (six or eight inches), buttons or reflectorized delineators can be used as lane lines. The use of buttons or delineators may increase the awareness of the HOV restrictions and serve as a physical reminder (as the tire passes over them) to violators. This could discourage some violations and could thereby aid enforcement. Word messages are generally not used in pavement markings for HOV lanes and the potential conflict with off-peak utilization would suggest they not be used under normal circumstances on concurrent HOV lanes on arterial roadways. The diamond symbol has been designated as the standard symbology and it should suffice in lieu of word messages.

An HOV lane on an arterial street could very well have additional signing requirements for turning and parking restrictions in order to improve traffic safety and capacity.

Restrictions on right-turns would be associated with a concurrent flow curb HOV lane. For curb bus lanes, right-turning vehicles are generally permitted to use the lane in order to execute the turn. The problem arises as to when the right-turning vehicle should be permitted to enter the curb bus lane. The legal entrance to the curb bus lane by right-turning vehicles may occur 1) at a close as

practicable distance prior to making the right turn,[4] 2) within one block of the right turn,[5] and 3) after the point where a sign states "buses and right-turns only."[6]

Restrictions on left-turns would be associated with a concurrent flow median HOV lane. The traffic lane configuration of the facility has the left-turn bay to the left of the median HOV lane thereby requiring a left-turn vehicle to weave across the HOV lane in order to enter the left-turn bay. The U.S. 1/ South Dixie Highway project had left-turns restricted because of 1) safety concerns regarding left-turn movements with a contraflow bus lane located on the other side of the raised median (the contraflow bus lane operated simultaneously with concurrent flow HOV lane), and 2) traffic flow and capacity considerations associated with the concurrent flow median HOV lane. Even when the contraflow lane was abolished and the express bus operation was transferred to the concurrent flow HOV lane, left-turns continued to be prohibited because of the second factor. The concurrent flow HOV lane has a high volume of carpools and if additional traffic such as vehicles maneuvering to make a left-turn used the HOV lane, the travel time and speed advantage of the HOV lane would be correspondingly lessened.[7]

In order for a curb HOV lane to properly operate, parking in the lane must be prohibited. For the Washington, D.C. curb bus lanes, wreckers remove illegally parked vehicles from certain key streets at the beginning of the restricted operations each day. On the other streets, vehicles are not removed, but often steel "boots" are fixed to the wheels to prevent the owner from removing the vehicle until paying the parking fine. Buses then have to pass any parked vehicle which has not been removed.

Recommendations for Enforcement

General recommendations on enforcement of HOV priority treatments on arterial streets and highways are presented on page117. In regard to concurrent flow HOV lanes, the following specific recommendations are offered.

- Enforcement of HOV lanes may have an additional concern with parking and turning restrictions. These restrictions may require more enforcement attention than violations of the HOV lane itself.
- For a median lane HOV treatment, use of left-turning bays (closed-off due to left turn restriction) have proven to be an effective area for enforcement vantage points and detention areas, when coupled with a special enforcement program.
- Signing and markings should conform rigidly to standards, but special supplemental signs should be used as needed. Special signing may be required to cover special provisions of

4. Dallas, Texas curb bus lanes
5. Washington, D.C. curb bus lanes
6. Denver, Colorado curb bus lanes
7. On the N. W. 7th Avenue median concurrent HOV lane, which is not included in this research, left turns that weaved across the HOV lane into a left-turn bay were permitted during the operation of the HOV lane. The project attempted to control this weaving through pavement markings on the HOV lane. This weaving did not pose a safety problem. One factor for the good safety record was the limited volume of traffic—less than 30 buses per three hour peak period—that traveled in the HOV (bus-only) lane.

the project, such as permitting special classes of vehicles to also use the HOV lane or establishing turning or parking restrictions. Limits of the HOV priority section should be clearly defined.

- For a median lane HOV treatment, cones or safety posts should not be employed to separate the HOV lane and general travel lanes. These implements can pose safety problems and do not favorably affect the violation rate.

- For a curbside lane HOV treatment, locations should be available or provided where officers can apprehend and issue citations to violators without encroaching onto the main roadway. The use of cross streets may be an appropriate detention area.

- For a curbside lane HOV treatment, the signing permitting right turns should specifically state the point at which a right-turning vehicle may enter the priority lane.

- Median lane concurrent flow HOV treatments should be enforced by selective or special enforcement efforts. The example cited on U.S. 1/South Dixie Highway in Miami is recommended for similar situations.

- Concurrent flow curbside lanes will generally experience significant violations of the various restrictions associated with the project. The degree to which these violations threaten the integrity of the HOV treatment is a subject of debate since curbside lanes do not generally produce significant travel time advantages for buses when compared to general lane speeds. Therefore, the enforcement program deployed should be responsive to the local goals for the project. Routine patrols (mobile or foot), could be justified as capable of producing a tolerable violation environment for such HOV projects. However, it is recommended that selective enforcement be periodically deployed to further enhance the credibility of 1) the HOV project, 2) the enforcement agency, and 3) traffic laws in general

- For a curbside HOV lane treatment, consideration should also be given to using passive enforcement tactics, such as forcing illegal HOV lane users to turn right (whether they intended to or not) in order to penalize violators by increasing route circuitry and travel time. By using such tactics, the time-consuming elements of apprehension, detention and issuing citations are avoided. However, a penalty is enforced nonetheless, and a larger number of violators can be "cited."

CONTRAFLOW LANES

A contraflow HOV lane is commonly a lane in the off peak direction reserved for HOV vehicles traveling in the peak direction. A specialized type of contraflow lane is the reversible lane in which a lane's traffic flow may be reversed in order to provide a reserved lane in the peak direction without reducing the capacity in the off-peak direction. A contraflow HOV lane can incorporate the median lane or the curb lane of a highway facility. Because of its nature, a reversible lane is almost always a median lane.

A contraflow HOV lane operating in the median lane is commonly associated with express bus service operating in a through mode or on a line-haul trip. Carpools may also be permitted to travel in the contraflow HOV lane. The major objective of the contraflow median HOV lane is to provide travel-time advantages to the HOV vehicles by bypassing traffic congestion in the general traffic lanes and traffic queues at signalized intersections. Because of this objective, the contraflow median lane generally operates during the peak-period over a distance of several miles. During the off-peak periods, the reverse flow lane may function as a through lane, a left-turn lane or a median lane closed to any type of traffic.

A contraflow HOV lane operating in the curb lane occurs on a facility which otherwise usually serves one-way traffic. This type of operation is commonly associated with local bus service making periodic stops for passenger loading and unloading. Carpools usually are not permitted to travel in the contraflow HOV lane, which is not unreasonable because of the stop-and-go bus movement occurring in the lane. The major objectives of the contraflow curb HOV lane is to 1) separate the different classes of vehicles—bus and auto—in order to improve traffic flow on the facility and traffic circulation in the CBD, and 2) provide a travel-time advantage for the HOV vehicles (i.e., local buses). The contraflow curb HOV lane can be either a 24-hour or peak-period operation over a distance ranging from several city blocks to several miles.

Enforcement of both types of contraflow lane treatments are concerned with 1) violators of the HOV restrictions and 2) violators of the supplemental traffic restrictions necessary to operate the contraflow lane. The violators of the supplemental traffic restrictions are frequently of much greater concern to enforcement officials. Supplemental traffic restrictions may involve turning movements across the HOV lane, and parking or stopping in the HOV lane.

Details of Projects Investigated

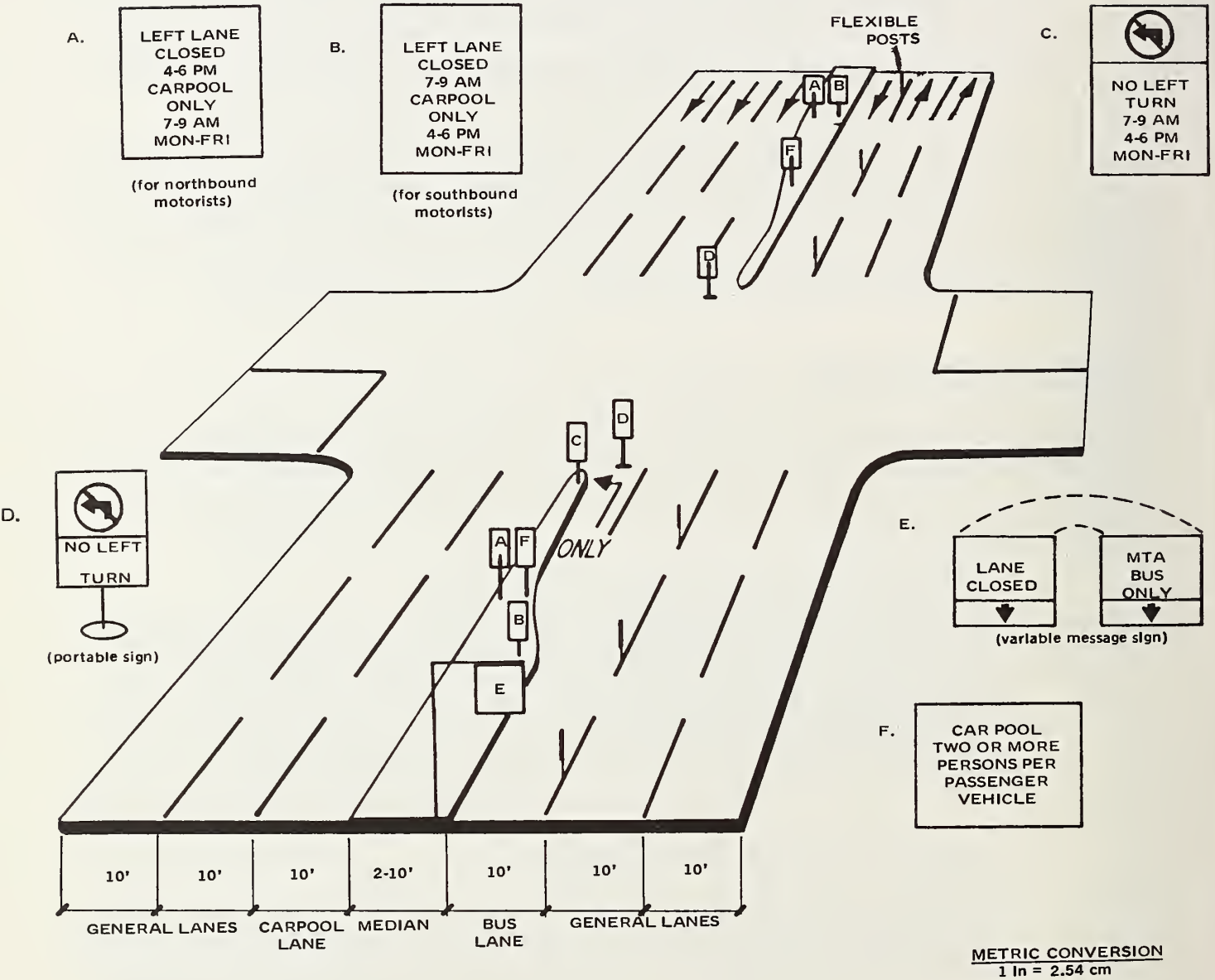
Enforcement of contraflow HOV lanes can be difficult and an important component of the project's operation. Four contraflow HOV lane projects (one median contraflow lane, one median reversible lane, and two curb lane applications) were investigated in detail. Project descriptions are given below and in Figures 19 to 22.

- U.S. 1/South Dixie Highway, Miami, Florida (Figure 19)
  This project included a concurrent flow median carpool lane, a contraflow median bus lane and signalization improvements on a 5.5 mile (8.9 km) segment of South Dixie Highway (U.S. 1). The six lane divided highway operated with a median contraflow lane inbound (northbound) in the outbound lanes from 6-9 AM and with a median contraflow lane outbound (southbound) in the inbound lanes from 4-7 PM. The hours were later reduced to 7-9 AM and 4-6 PM. Left-turns across the median HOV lane were prohibited. The contraflow lanes were initiated on July 22, 1974, and terminated on April 5, 1976. The termination was due to safety and financial considerations associated with operation of the lane.

- N. W. 7th Avenue, Miami, Florida (Figure 20)
  This project included express "Orange Streaker" buses operating in a reserved bus lane for 9.9 miles (16.0 km). For 7.3 miles (11.8 km), the reserved bus lane was a reversible lane while the other 2.6 miles (4.2 km) the bus lane consisted of a concurrent flow median lane. The reversible bus lane operated inbound (southbound) from 6:00-9:30 AM and outbound (northbound) from 3:00-6:30 PM. During the other times of the day, the reversible lane operated as a dual left-turn lane. Express buses operated in the reversible bus lane with 1) signal preemption (see next section on "Signal Preemption"), 2) signal progression, or 3) a combination of the two. The N.W. 7th Avenue bus priority system commenced August 19, 1974, but the reversible bus lane did not begin operating until January 20, 1975. It operated until March 12, 1976, at which time the project was terminated and the express bus operation was transferred to the nearby Interstate 95 concurrent flow HOV lanes.

- Marquette/Second Avenues, Minneapolis, Minnesota (Figure 21)
  Marquette and Second Avenues form a pair of one-way streets. With an overall objective of

FIGURE 19
US 1/SOUTH DIXIE HIGHWAY (CONTRAFLOW LANE), MIAMI, FLORIDA



METRIC CONVERSION
1 In = 2.54 cm
1 ft = 0.3 m
1 mi = 1.61 km

AASHTO DESIGN FACTORS

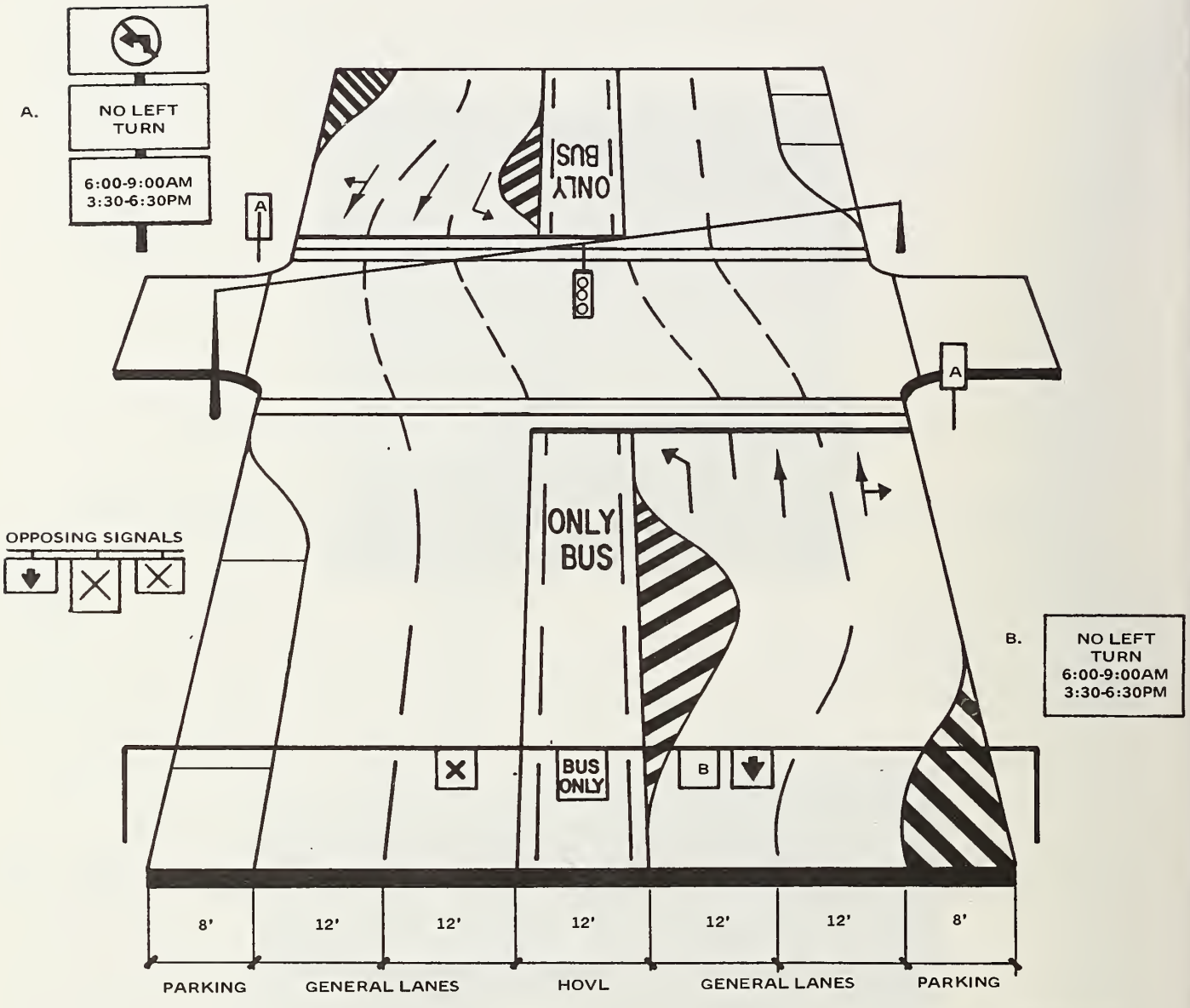
ALIGNMENT: linear
VERTICAL SIGHT DISTANCE: adequate to poor
POSTED SPEED: 35 mph
ROADSIDE HAZARDS: poles within several feet of roadway

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: none
ADVANCED WARNING SIGNS: non-standard
RESTRICTED LANE SIGNS: non-standard
END OF HOVL SIGNS: none
DIAMOND SYMBOL: none
HOVL DELINEATION: skip white marking and flexible posts

U.S. 1/SOUTH DIXIE HIGHWAY (CONTRAFLOW LANE), MIAMI, FLORIDA

FIGURE 20
NW 7TH AVENUE (CONTRAFLOW SECTION), MIAMI, FLORIDA



METRIC CONVERSION
1 In = 2.54 cm
1 ft = 0.3 m
1 mi = 1.61 km

AASHTO DESIGN FACTORS

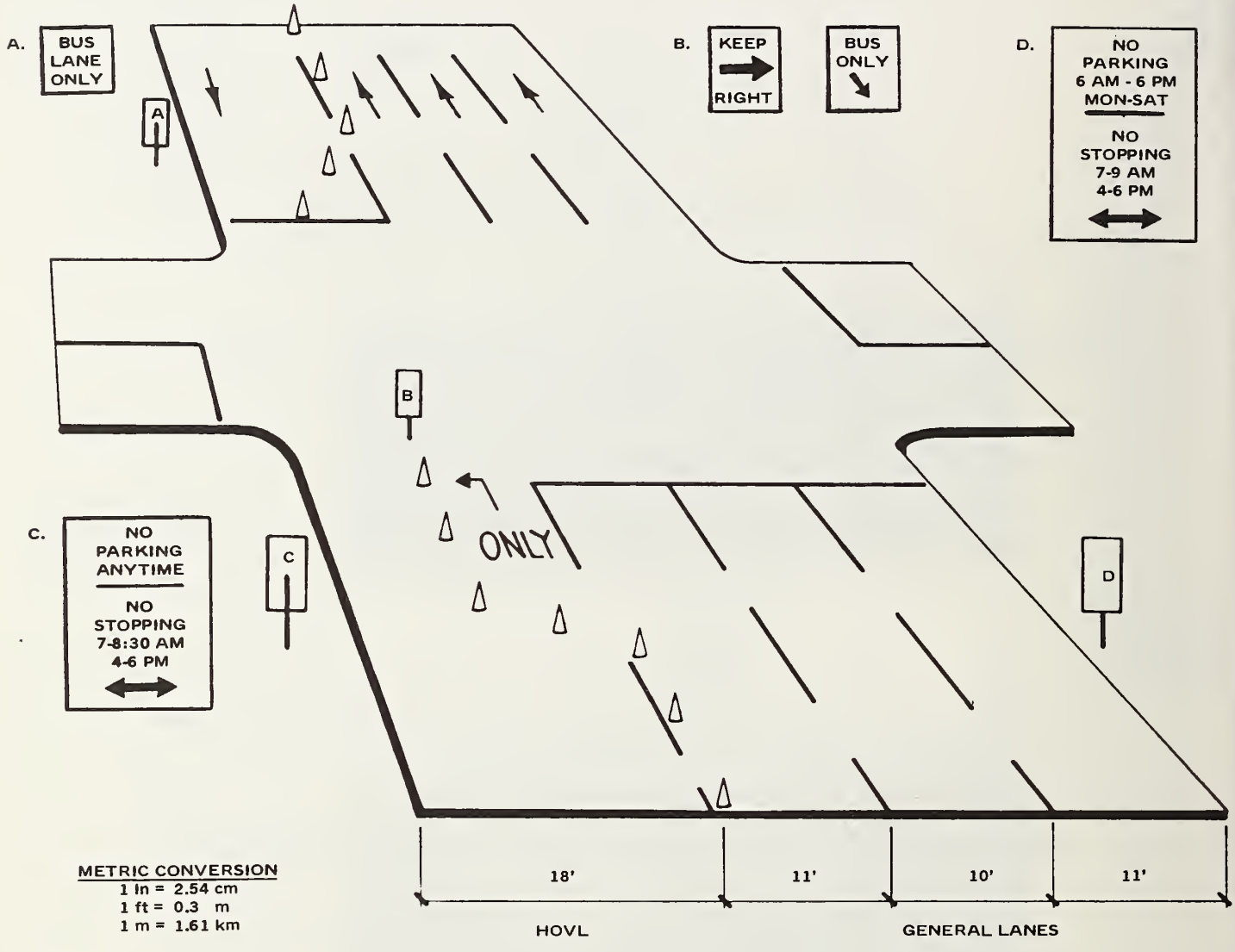
ALIGNMENT: linear
VERTICAL SIGHT DISTANCE: good
POSTED SPEED: 35 mph
ROADSIDE HAZARDS: none

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: overhead three lanes
ADVANCED WARNING SIGNS: none
RESTRICTED LANE SIGNS: none
END OF HOVL SIGNS: non-standard
DIAMOND SYMBOL: none
HOVL DELINEATION: solid and skip yellow marking

NW 7TH AVENUE (CONTRAFLOW LANE), MIAMI, FLORIDA

FIGURE 21
MARQUETTE/SECOND AVENUES, MINNEAPOLIS, MINNESOTA



AASHTO DESIGN FACTORS

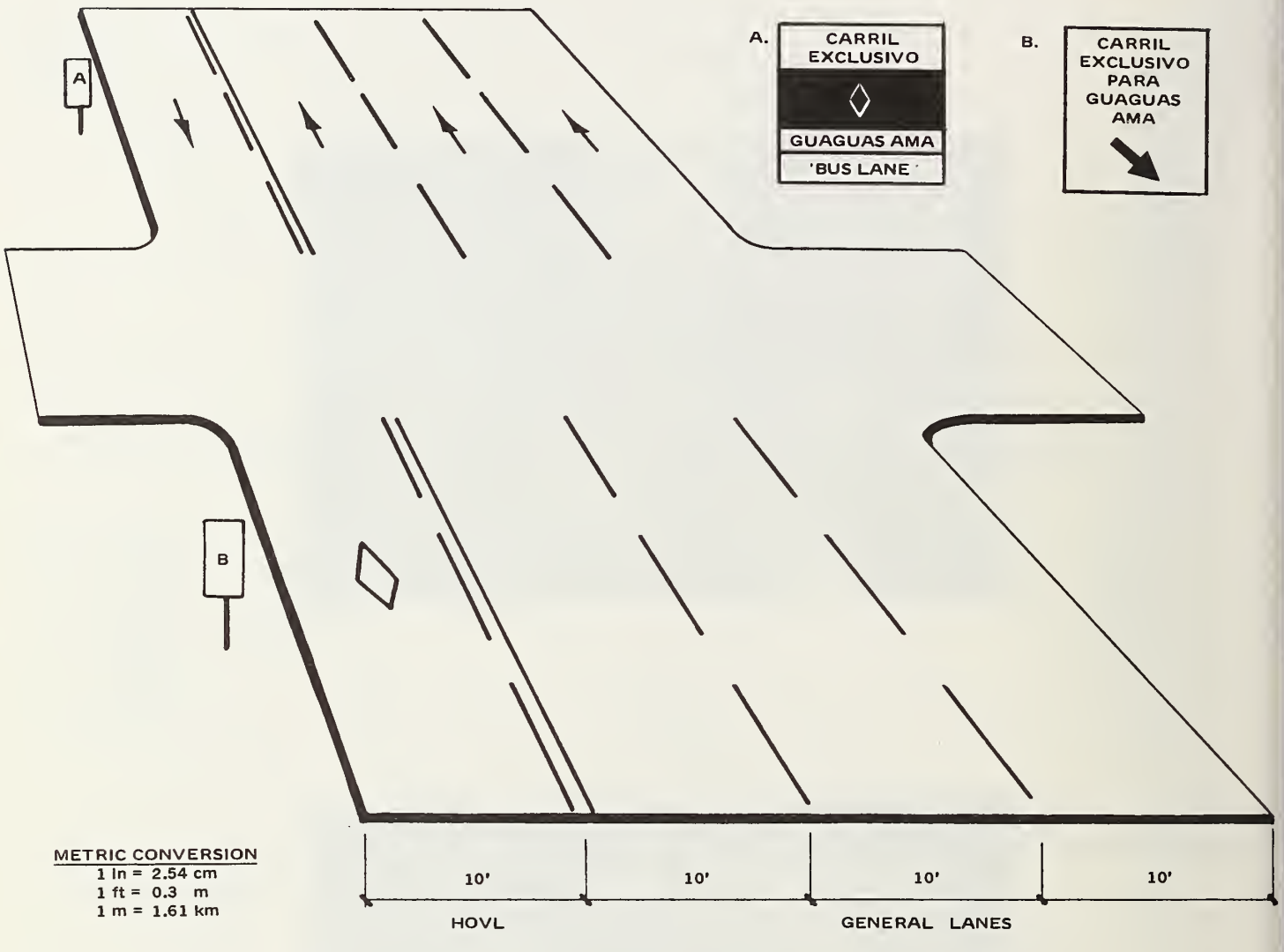
ALIGNMENT: linear
VERTICAL SIGHT DISTANCE: good
POSTED SPEED: 25 mph
ROADSIDE HAZARDS: poles within several feet of roadway

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: none
ADVANCED WARNING SIGNS: none
RESTRICTED LANE SIGNS: non-standard
END OF HOVL SIGNS: none
DIAMOND SYMBOL: none
HOVL DELINEATION: portable traffic cones with signs mounted

MARQUETTE/SECOND AVENUES, MINNEAPOLIS, MINNESOTA

FIGURE 22
PONCE DE LEON/FERNANDEZ JUNCOS AVENUES, SAN JUAN, PUERTO RICO



METRIC CONVERSION
1 In = 2.54 cm
1 ft = 0.3 m
1 m = 1.61 km

AASHTO DESIGN FACTORS

ALIGNMENT: varies
VERTICAL SIGHT DISTANCE: good to poor
POSTED SPEED: 25 to 35 mph
ROADSIDE HAZARDS: poles within several feet of roadway

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: none
ADVANCED WARNING SIGNS: none
RESTRICTED LANE SIGNS: standard
END OF HOVL SIGNS: standard
DIAMOND SYMBOL: standard
HOVL DELINEATION: solid and skip white line marking

PONCE DE LEON/FERNANDEZ JUNCOS AVENUES, SAN JUAN, PUERTO RICO

improving access to the CBD core, 1.8 miles (2.9 km)—0.9 miles (1.4 km) on each facility—of contraflow curb bus lanes were opened in September, 1974. The contraflow lanes operate 24 hours each day. The contraflow lanes are wide enough to allow two vehicles to pass in the lane, thereby permitting taxis and delivery trucks to use the contraflow lane in the off-peak. In order to maintain the same number of general traffic lanes in the peak periods with the establishment of the contraflow lanes, parking and stopping in the opposite curbside lane is prohibited during these periods.

- Ponce de Leon/Fernandez Juncos Avenues, San Juan, Puerto Rico (Figure 22)
  Ponce de Leon and Fernandez Juncos Avenues comprise a one-way pair of arterials connecting two major sections of San Juan. The arterials are four to five lanes wide. The left curb lane serves as the contraflow bus lane in order for the passenger door to be curbside for collection/distribution of passengers. Parking in the contraflow lane is restricted but left turns across the contraflow lane are permitted. The daily total vehicular volume ranges between 30,000 to 40,000 vehicles. There are a total of 13.6 miles (21.9 km) of contraflow bus lanes with the first section being implemented in May, 1971.

Table 23 presents the national standards applicable to HOV priority treatments on arterial streets and highways. All four projects predated the March, 1975 publication of the MUTCD standards for HOV facilities. The AASHTO geometric standards do not specifically address a contraflow or reversible HOV lane treatment, but it does provide generalized guidelines for the application of "reverse-flow" lanes and reserved bus lanes on city streets and arterials.[8] AASHTO limits the use of reverse flow lanes on undivided streets . . . to "where there is continuity in the route and width of street, where there is no median and where left turns and parking can be restricted." The concern with turning and parking restrictions is to insure adequate capacity in the minor (non-peak) direction.

The U.S. 1/South Dixie Highway project was deficient in lane widths, proximity of roadside hazards and sight distance on occasion. The project utilized non-standard restricted lane signing located overhead as a changeable message sign and in the median as a static sign. The diamond pavement marking is not used. The project used polyvinyl chloride (PVC) safety posts at a 40 feet (12 m) spacing to differentiate between the contraflow lane and the general traffic lanes.

On the N.W. 7th Avenue project, there were no significant deviations from AASHTO's geometric standards. All lanes were 12 feet (3.6 m) in width and 14 feet (4.2 m) on curb lanes. The only two minor variances were a narrow right-of-way in one limited section and short lane alignment transitions in another section. The N.W. 7th Avenue bus priority system project was a temporary project (until express bus operations transferred to I-95) therefore the reduced taper was acceptable on this temporary basis. As the N.W. 7th Avenue project was soon to be terminated after the January 1, 1976 compliance date, the MUTCD requirements for HOV lanes were not implemented.

The Marquette/Second Avenues project conforms to AASHTO standards except for the proximity of roadside hazards. The HOV lane-control signing on this project is non-standard and does not include signing for advance warning of the HOV lane or end-of-the-HOV lane. In addition, the lane control signing specifies that only buses can use the contraflow lane. The diamond pavement marking is not used. The contraflow lane is separated from the general travel lanes by portable traffic cones with "buses only" signing mounted on top.

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8. AASHTO, op. cit., pp. 180-183, 646-648 and 666-668.

The Ponce de Leon/Fernandez Juncos Avenues project is deficient at locations in lane width, proximity to roadside hazards and sight distance. The project has standardized lane-control signing (in Spanish) along the roadside and uses the diamond pavement marking. There is no physical separation between the curb contraflow lane and the general traffic lanes.

The geometric deficiencies regarding lane width and proximity of roadside hazards is quite common for urban areas and especially for downtown areas where available right-of-way for streets and highways is a scarce commodity. These deficiencies do not affect enforcement operations or the tendency to violate the HOV lane.

AASHTO and the MUTCD recommend the use of overhead lane signals to control lane usage on reverse-flow (or reversible lane) operations.[9] The MUTCD states that each lane to be reversed shall have signal faces with a DOWNWARD GREEN ARROW on an opaque background, and a RED X symbol on an opaque background. Each nonreversible lane immediately adjacent to a reversible lane shall have a DOWNWARD GREEN ARROW displayed to traffic traveling in the permitted direction and a RED X symbol displayed in the opposite direction. The visibility of the colors of the various displays is prescribed to be one-fourth mile (0.4 km).

The N.W. 7th Avenue project complied with the requirements for the lane-use control signals, including the appropriate signals for the adjacent travel lanes, except for the visibility requirement. The reversible lane was controlled by bi-directional overhead changeable message signals (CMS) having the selectable displays as shown in Table 26.

TABLE 26
CHANGEABLE MESSAGE SIGNAL DISPLAYS (N. W. 7th AVENUE)

TIME PERIOD	DIRECTION	
	SOUTHBOUND	NORTHBOUND
AM PEAK	message—"Buses Only"	figure—red X
PM PEAK	figure—red X	message—"Buses Only"
OFF PEAK	figure—dual left-turn arrow*	figure—dual left-turn arrow*

*CMS near signalized intersections with left turn bays would display a red X figure in the off peak to prevent both the left turn lane and reversible lane from being used by left-turn traffic.

The spacing of the CMS was approximately one-fifth mile (0.3 km), however, the optical output of the fiber optic CMS was inadequate with only about one-tenth mile (0.2 km) visibility. Additionally, the CMS were not explicitly supported by any fixed message signs that identified the bus only use of the reversible lane.

The U. S. 1/South Dixie Highway project utilized overhead variable message signing to designate the HOV lane. The black-on-white sign read MTA BUS ONLY with a downward arrow for the contraflow

9. Ibid, pp. 646-648.
United States Department of Transportation (Federal Highway Administration), op. cit., pp. 249-252.

lane traffic. The other side of the sign read LANE CLOSED also with a downward arrow. These signs were blank during non-HOV operating hours.

Operational Results

The extent of the enforcement requirements for an HOV project is dependent in part on the operational characteristics of the project. The operational data for each project are displayed in Table 27. From this table, several of the more significant results are:

- A comparison of bus speeds on each project shows that the median HOV lane is associated with express bus service and the curb HOV lane is associated with local bus service. The median lane projects of U.S. 1/South Dixie Highway and N.W. 7th Avenue respectively experienced bus speeds of 36 and 29 mph (58 and 46 kph). The curb lane projects of Marquette/Second Avenues and Ponce de Leon/Fernandez Juncos Avenues respectively experienced bus speeds of 11 and 12 mph (18 and 19 kph).

- The HOV lanes on the projects illustrate the efficiency of the operation. The contraflow curb lane of Ponce de Leon Avenue moved 42 percent of the person-movement in less than 3 percent of the vehicles. The contraflow bus lane of the U.S. 1/South Dixie Highway project moved 8 percent of the person movement in less than 1 percent of the vehicles. The reversible bus lane of the N.W. 7th Avenue project moved 24 percent of the person movement in 1 percent of the vehicles.

- Total peak volume for the facility decreased with the establishment of the contraflow lane. The decrease was 2 percent on the U.S. 1/South Dixie Highway project, 14 percent on the N.W. 7th Avenue project and 15 percent on the Marquette/Second Avenues project.

- The total facility accident rate increased on all projects after the contraflow lane was established. Accident data was not available on the Marquette/Second Avenues project.

Enforcement Characteristics

Chapter 3 presented details on HOV projects related to 1) the enforcement program, 2) the enforcement problems and deficiencies, and 3) the enforcement program's performance. These enforcement elements are summarized here for the four contraflow HOV projects.

- U.S. 1/South Dixie Highway, Miami, Florida
  The enforcement of this project is divided between two agencies—the Metropolitan Dade County and City of Miami police departments. The project used special enforcement tactics consisting of stationary patrols located in the left-turn bays, which are not in use because of left-turn restrictions during HOV operations. The special enforcement program and closing of the left-turn bay was due in part to the operation of concurrent flow HOV lane. The left-turn bay serves as a vantage point to monitor the HOV lane operations and as a refuge area for issuing citations. Violators may be waved into the left turn bay or apprehended via pursuit with the enforcement vehicle using the contraflow lane if necessary. Left-turn violations across the contraflow lane present the greatest concern because of the accident potential of this maneuver. On any day, six to ten officers comprise the special enforcement team. This required a special budget funded by the project management agency and not the enforcement agencies.

TABLE 27

OPERATING CHARACTERISTICS ON CONTRAFLOW HOV LANE PROJECTS

VARIABLE	UNIT	PROJECT/CONDITION						
		U.S. 1/South Dixie Highway[a]		N.W. 7th Avenue		Marquette/Second Avenues		Ponce de Leon Avenue
		Before	Bus-Only	Before	Bus-Only	Before	Bus-Only	Bus-Only
Critical Peak Period	—	7 - 9 AM; 4 - 6 PM	7 - 9 AM; 4 - 6 PM	4 - 6 PM	4 - 6 PM	24 Hour	24 Hour	7 - 9 AM
Length of HOV Lane	Miles	—	5.5	—	7.3	—	1.8	13.6
Total Peak Directional Lanes	Lanes	3	4	2	3	4	4	4-5
Number of HOV Lanes	Lanes	—	1	—	1	—	1	1
Volume - All Lanes	Vehicles	14,674	14,330	1,825	1,569	2,239	1,671	5,574
Volume - HOV Lanes	Vehicles	—	60	—	21	—	170	129
Volume - HOV Lanes (bus only)	Vehicles	—	60	—	21	—	170	129
HOV Lanes/Total Volume	%	—	0.4	—	1.3	—	10.2	2.3
Auto Occupancy - All Lanes	PPV	1.38	1.60	1.45	1.40	NA	NA	1.46
Person Throughput - All Lanes	Persons	20,250	22,640	2,641	2,900	—	—	13,749
Person Throughput - HOV Lanes	Persons	—	1,903	—	710	—	—	5,798
HOV Lanes/Total Throughput	%	—	8.4	—	24.5	—	—	42.1
Speed - General Lanes	MPH	19.4	16.9	19.8	25.0	8.8	8.8	NA
Speed - HOV Lanes	MPH	—	36.7	—	28.8	—	11.4	12.1
Travel Time - General Lanes	Minutes	17.0	19.5	22.1	17.5	4.6	4.6	NA
Travel Time - HOV Lane	Minutes	—	9.0	—	15.2	—	3.6	67.4
Accident Rate	Acc/mvm	7.5	12.1	10.4	15.3	NA	NA	6.8

a. This facility also has a concurrent flow carpool lane

Metric Conversion

1 mile = 1.61 kilometers

- N.W. 7th Avenue, Miami, Florida
  This project was enforced using routine enforcement on mobile line patrol. On the average, one patrol vehicle was on N.W. 7th Avenue at any given time. Violations of the bus-only restriction were uncommon because a non-bus vehicle traveling in the reversible lane is very conspicuous. The main concern was violations of the turning or parking restrictions. The enforcement strategy generally employed to cope with the left-turn problem was to randomly patrol the facility scanning for violations. On occasion, the agencies would assign extra patrols to effect a "blitz" or crackdown on violations, but the left-turn maneuver could be executed so quickly and at so many locations, that neither strategy was fully successful in reducing the number of violations. Another technique was to post a stationary patrol on a side street to observe left-turns onto their street from N.W. 7th Avenue. Although this technique was effective at high violation locations, the one-man-per-street feature precluded any widespread application or significant reduction in facility-wide violations.

- Marquette/Second Avenues, Minneapolis, Minnesota
  The Minneapolis Police Department enforces the HOV lane restrictions using routine enforcement because the number of buses in the contraflow lane essentially makes the lane self-enforcing. However, violations of the no stopping/no parking restriction was necessary to provide the same number of general travel lanes after installation of the contraflow lane. Two to five "meter monitors" are responsible to enforce the no stopping/no parking restrictions throughout the downtown area. Enforcement is hindered by the fact that the meter monitors may not pursue violators but must apprehend them while the violator is stationary.

- Ponce de Leon/Fernandez Juncos Avenues, San Juan, Puerto Rico
  The San Juan Police Department enforces the HOV lane restrictions using routine enforcement because the number of buses in the contraflow lane essentially makes the lane self-enforcing. Four to six officers regularly patrol the section involving the contraflow lane. Violations of a parking restriction, which may disrupt the operation of the contraflow lane, provide a greater enforcement need.

The violation data are presented in Table 28. From this table, several of the more significant results include:

TABLE 28
ENFORCEMENT CHARACTERISTICS ON CONTRAFLOW LANE PROJECTS

VARIABLE	PROJECT			
	South Dixie Highway	N.W. 7th Avenue	Marquette/Second Avenues	Ponce de Leon/ Fernandez Juncos Avenues
	7-9 AM and 4-6 PM	4-6 PM	3-6 PM	24 Hours
HOV Lane Volume	60	21	170	129
Number of Violators	0	0	0-1	0-2
Violation Rate (%)	0	0	0-1	0-2
Number of Citations	0	0	0	2-3 per month
Apprehension Rate (%)	-----	-----	-----	-----

- The violation rates on all three contraflow lanes have been estimated to be nearly zero percent by project officials.

- Because of the very low violation rate of the contraflow lane restrictions, very few citations for this violation are written. To any extent, only the Ponce de Leon/Fernandez Juncos Avenues project has such citations. Many of these citations are issued to motorists temporarily using the contraflow lane in order to facilitate left-turns.

On a bus-only contraflow lane operation, the main concern for enforcement officials is generally not associated with violations of the bus-only restriction, but with possible violations of any associated turning or parking restrictions. Illegal turns are hazardous movements and can adversely impact safety. Violations of the bus-only restriction are uncommon because 1) bus volumes in the contraflow lane can be high and this provides a self-enforcing feature, 2) a non-bus vehicle traveling in the contraflow lane is very conspicuous to police officers, and/or 3) the general lane traffic is moving in the opposite direction of the contraflow lane. With a bus/carpool contraflow lane (such as Kalanianaole Highway in Honolulu, Hawaii), violations may be more prevalent because a violating vehicle is no longer as conspicuous as in the case with a bus-only restriction.

Despite a low violation rate of the contraflow lane, contraflow lane operations generally place additional emphasis on the enforcement of the particular facility. This is especially true for a peak period contraflow lane where the traffic control measures are temporary. More policing and manpower may be required for system surveillance, especially at terminal or cross-over points. Enforcement of the contraflow HOV project can occur by means of routine (standard) patrol or a special patrol. Because of the extra policing and monitoring a contraflow lane may require, a special enforcement patrol may be assigned to the project, as in the case of the U.S. 1/South Dixie Highway project. HOV enforcement is made more difficult if the facility lacks a refuge area, vantage point, or a physical separation between the HOV lane and general travel lanes.

Geometric Standards Related to Enforcement

The enforcement process can be hindered by inadequate vantage points, passing lanes for apprehension and/or refuge areas for presenting the citation. The extensive lane width of 20 feet (6 m) applied to the Marquette/Second Avenues contraflow lanes is an example of curbside geometrics compatible with enforcement. This wide lane permits vehicles to be detained at the curb and cited, while simultaneously allowing traffic to pass by with minimum interruption. The U.S. 1/South Dixie Highway incorporates geometrics which facilitate enforcement since the median or left-turn bays can be utilized as detention areas. Generally, geometrics least conducive to effective enforcement involve median contraflow or reversible lanes located on facilities without a physical median. This operation requires that the enforcing officer cross several lanes of traffic in order to access the contraflow lane and subsequently apprehend a violator by again weaving back across the traffic lanes. This enforcement process can be both hazardous and time-consuming.

The geometrics for the terminal treatments of an HOV project can impact safety and thereby influence enforcement operations. The very nature of a contraflow lane treatment requires that a lane in the off-peak direction be taken away in order to establish the contraflow lane. This "taking of a lane" will produce some necessary merging movements. Appropriate signing and pavement markings

are necessary to adequately inform motorists of these terminal treatments. A one-way configuration requires a curb bus lane, generally on the side of the roadway that permits the bus to pick-up and discharge passengers. The vehicles would enter and exit the contraflow curb lane by turning from cross streets intersecting the HOV lane. For a median contraflow lane, the vehicles would enter and exit the contraflow lane by weaving through the general traffic lanes, through a cross-over of some type or by executing turning movement from a cross street. Quite possibly, special traffic control devices and supervisory personnel can be required to guide traffic through the entrance and exit points to the contraflow lane.

Traffic Control Related to Enforcement

Contraflow systems require concise and easily comprehensible signing in order to alleviate confusion resulting from the extreme variances in lane usage between a peak-period bus-only lane and off-peak uses for the lane. Therefore, the traffic control devices must effectively communicate those standards of proper driver behavior such that 1) it is unlikely for a motorist to violate system restrictions unintentionally or without neglect, and 2) a definitive legal basis is established.

Overhead lane designation signals, which are required for reversible lanes by both AASHTO and MUTCD, can effectively relieve driver confusion and provide a more definitive basis for enforcement. Overhead lane designation signals are particularly applicable where there exists extensive visual clutter to make roadside signing less effective.

Standard displays for HOV projects, as established by the MUTCD in March, 1975, include lane-use designation signs and markings, lane-use descriptions, advanced warning signs and end-of-project signs. Advanced warning signs are highly desirable, especially in locations where a large number of unfamiliar motorists travel the contraflow lane facility. In addition, advanced warning signs can initiate early merging movements prior to the terminal locations. Mainline contraflow lane sections must often incorporate traffic cones, gates, special signs, etc., in order to maintain limited access/egress. Specific deployment of special traffic control devices concerning both lane-use and supplementary restrictions is, of course, site specific. However, deployment must be sufficient at intermediate access locations to inform motorists of the contraflow lane restrictions and/or physically obstruct or impede undesirable movements.

An undesirable movement universal to all median applications is the illegal turning movement across the contraflow lane. Generally, traffic control devices can only define traffic restrictions and enforcement personnel become charged with inducing a sufficient level of compliance. The overwhelming majority of accidents involving a contraflow lane vehicle were associated with a turning or crossing maneuver. These maneuvers may involve 1) a vehicle turning left off the main facility, 2) a vehicle crossing or turning onto the main facility from the side street, and 3) a pedestrian crossing the main facility. The overwhelming causative factor expressed by project officials for the occurrence of these contraflow lane accidents involving crossing maneuvers is the inability of motorists or pedestrians to perceive a facility's "wrong-way" flow of the contraflow lane.

Finally, end-of-project signing is important to establish legal boundaries for the HOV system. Such signing is of particular importance when used to help identify the terminal location where contra-

flow traffic merges back into the general-use lanes.

Recommendations for Enforcement

General recommendations for enforcement of HOV priority treatments on arterial streets and highways are presented on page 117. In regard to contraflow HOV lanes, the following specific recommendations are offered.

- In addition to HOV lane violations, enforcement also needs to focus on turning and parking restrictions. These restrictions may pose greater responsibilities for enforcement.
- Geometric and/or traffic control techniques intended to eliminate or physically impede access/egress at intermediate intersections greatly enhances enforcement on contraflow facilities, and should be deployed where possible.
- Overhead lane-use signals and signs should be used, especially where extensive visual clutter exists lessening the effectiveness of roadside signing.
- The use of temporary traffic control devices, such as cones, gates, and signs on stanchions, have proven to be effective in eliminating illegal turns across the contraflow lanes on projects with physical medians. The elimination of illegal crossing turns on projects without physical medians will require site specific enforcement.
- If possible, curbside contraflow lanes should be wide enough for a bus to safely pass a disabled bus. Wide lanes enhance enforcement by providing 1) an enforcement vantage point, 2) a passing lane for violator apprehension, and 3) a detention/citation area.
- If possible, median contraflow lanes should have a median from which enforcement officers can monitor the project's operation. This raised median coupled with closed left-turn bays or mountable curbs, provides the police with suitable areas for surveillance, apprehension and issuing the citation. Without this median, enforcement will be increasingly difficult by requiring police to cross the general traffic lanes.
- Routine line patrols should be adequate for enforcing many contraflow HOV projects. However, extensive turning restrictions when coupled with very little geometric and/or physical control of such restrictions can easily produce a significant amount of illegal and hazardous turning maneuvers. Such hazardous maneuvers could threaten the project's continuation and seriously compromise the safety of the motoring public. Therefore, it is recommended that selective and special enforcement strategies be considered in such situations. Specific selective or special enforcement tactics may include stationary or mobile patrols. In either case, provisions should be made for readily-accessible refuge areas for the detention of violators.
- An effective but somewhat labor-intensive enforcement technique for left-turn violations is the stationing of an officer on the side-street where a violator can easily be apprehended upon completion of the illegal left-turn. This non-hazardous, non-disruptive and inconspicuous enforcement technique is particularly applicable to locations suffering high incidences of left-turning violations.

SIGNAL PREEMPTION

A signal preemption system provides buses with a capability to control the traffic signals in order

to obtain preferential treatment at signalized intersections. Signal preemption produces travel time savings to buses through the provision of increased green time when the applicable vehicle is approaching the signal. Signal preemption generally has the capability to 1) extend the main street green phase and/or, 2) accelerate the side street phase in order to advance a main street green signal. In short, signal preemption provides the bus with a high probability of receiving a green signal phase upon its arrival at each equipped traffic signal. Travel time savings to the bus can be further increased by the provision of a reserved lane for the bus, thereby allowing the bus to bypass any traffic queues and congestion, especially at the traffic signals.

Signal preemption priority treatment can be associated with both express bus service and local bus service. Preemption design is simplified under an express bus mode of operations. Once the detector receives the signal preemption transmission from the bus, the arrival time for the bus at the signalized intersection can be more accurately predicted for express bus service since express buses generally try to travel at a constant speed with no stops for passenger loading and unloading. On the other hand, local buses travel at variable speeds with sporadic stops, and create difficulties with respect to predicting their arrival at intersections.

Signal preemption systems operate through some mechanism to transmit the proximity of the bus to a receiver at the signalized intersection. In general, bus priority signal preemption systems contain four basic components: 1) transmission component, 2) detection component, 3) communication component, and 4) logic unit. The bus presents its location by transmitting a certain signal(s) to a detector. This information is then communicated to the logic unit which adjusts the traffic signal in a prescribed manner. Current state-of-the-art transmission and detection systems include 1) optical signals, 2) radio signals, and 3) electro-magnetic signals.

Details of Project Investigated

This research examined one signal preemption HOV project—the N.W. 7th Avenue Bus Priority System in Miami, Florida—to identify possible impacts these elements may have on the safety of the project. This project is illustrated in Figure 23.

The N.W. 7th Avenue Bus Priority System operated in the peak periods (6:00 to 9:30 AM and 3:00 to 6:30 PM) from August, 1974, to March, 1976, at which time the bus service was transferred to the concurrent flow HOV lanes on Interstate 95. There was an evaluation of five distinct operating stages on the N.W. 7th Avenue phase combining differing signal strategies and reserved bus lane treatments. For this research, the interest is with Stage 1-buses operating in mixed-mode traffic with signal preemption.

A total of 37 traffic signals were equipped with signal preemption equipment. The signal preemption system for the N.W. 7th Avenue project was of the optical variety. An optical transmitter, which emitted an intense, white stroboscopic light in front of the vehicle was mounted atop each of the express buses. The receiver was suspended on a span wire near the signal and had a reception zone of about 30^{o}, thus when properly positioned it could receive the optical signal (once in range) continuously until the bus passed under the receiver. The reception distance of the receiver was variable and in this application was set for 1,800 feet (540 m). A bus traveling at 30 mph (48 kph) would take

41 seconds to travel the distance, allowing sufficient time for signal preemption to orderly override the signalization.

Once a bus was detected by the receiver (after six seconds of continuous reception to avoid false calls due to spurious light signals), the preemption phase selector took command of the traffic controller and advanced or skipped into the desired preemption phase. The different possibilities are summarized as follows:

a) If the signal was already in the proper phase (main street green), the phase selector would hold the controller in that phase until the bus call expired. If, for some reason, the bus call was extended for a length of time (bus forced to stop or a long platoon of buses), a "call limit timer" set for 120 seconds would interrupt the detector call and release the controller to allow the cross street to be serviced.

b) If the signal was in a cross street phase or any other non-main street green phase, the phase selector would advance the signal off that phase and skip any other intermediate phases to bring the signal to the main street green or bus approach phase. If the bus call arrived within the minimum initial sequence or a pedestrian phase, those time sequences would be fully completed before the forceoff to the main street green phase could be affected.

With a signal preemption system, there is no need for system activation other than the bus driver activating the transmitter before his trip through the system. The transmitter then remains activated throughout the priority section.

A signal preemption system does not directly involve geometric design elements. Traffic control devices used in conjunction with signal preemption involves only traffic signals and the necessary preemption equipment. The MUTCD contains no guidelines and standards for traffic signal preemption.

Table 23 presents the national standards applicable to HOV priority treatments on arterial streets and highways. For the N.W. 7th Avenue project, there were no significant deviations from AASHTO geometric standards. All lanes were 12 feet (3.5 m) standard width, from 14 feet (4.2 m) on curb lanes. The only minor variance was the narrow right-of-way in the southern section. In the establishment of the restricted bus lane, non-standard HOV signing was used without the diamond symbol for pavement marking. This project was terminated several months after the MUTCD guidelines for HOV lane signing and pavement marking were to be in effect.

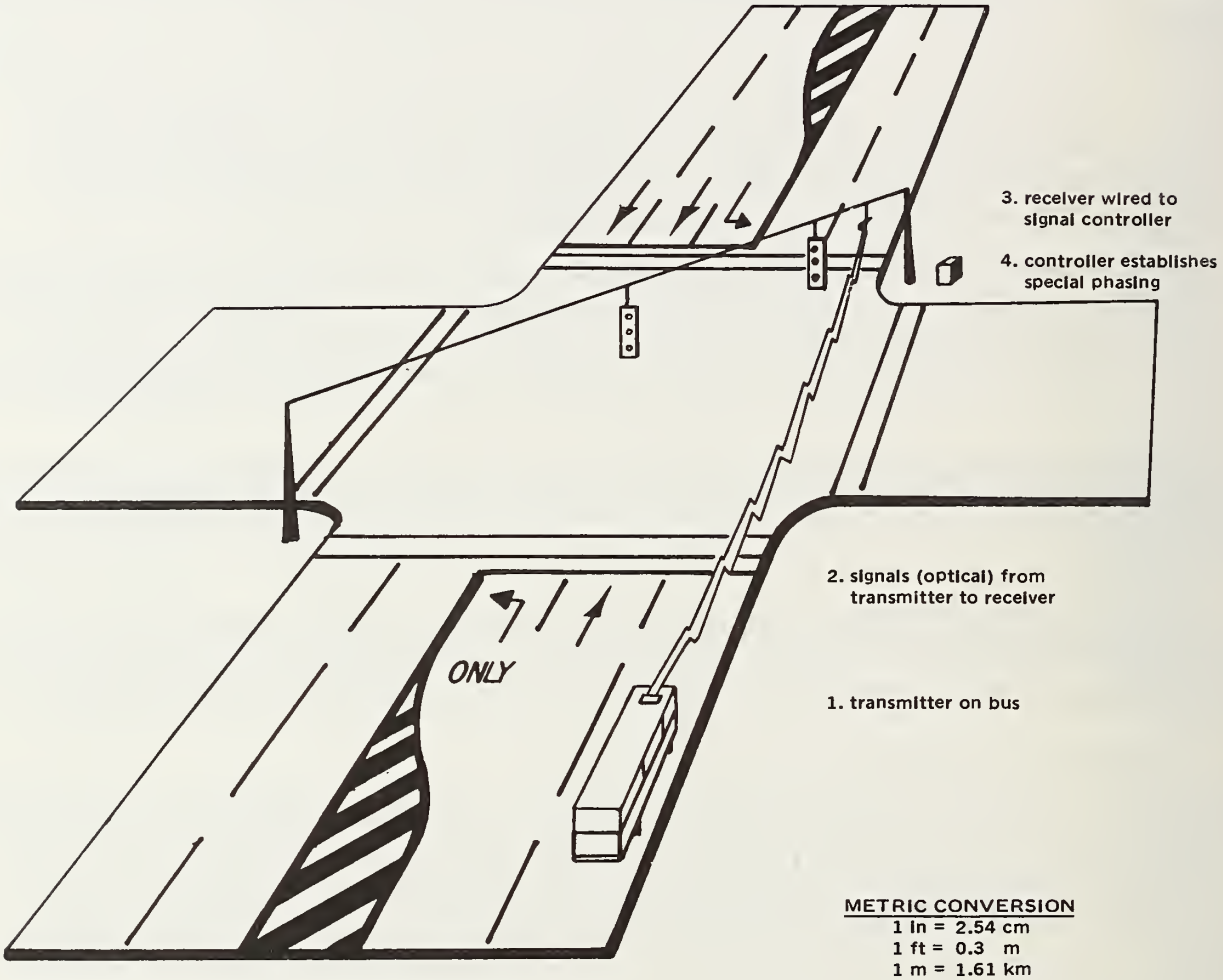
Operational Results

The extent of the enforcement requirements for an HOV project is dependent in part on the operational effectiveness of the project. The operational data for the N.W. 7th Avenue project are presented in Table 29. From this table, several of the more significant results are summarized below.

- Because of higher traffic volumes and the introduction of the express bus service, total person throughput on N.W. 7th Avenue increased for both peak periods between the before and after conditions.

- Vehicle speeds for both auto and bus increased between the before and after conditions. A fully actuated signal operation system for N.W. 7th Avenue was implemented at the same time that the signal preemption was introduced. Since the entire facility was affected by

FIGURE 23
NW 7TH AVENUE (SIGNAL PRE-EMPTION), MIAMI, FLORIDA



AASHTO DESIGN FACTORS

ALIGNMENT: linear
VERTICAL SIGHT DISTANCE: good
POSTED SPEED: 35 to 45 mph
ROADSIDE HAZARDS: poles within several feet of roadway

MUTCD DESIGN FACTORS

LANE-USE CONTROL SIGNALS: none
ADVANCED WARNING SIGNS: none
RESTRICTED LANE SIGNS: none
END OF HOVL SIGNS: none
DIAMOND SYMBOL: none
HOVL DELINEATION: none

NW 7TH AVENUE (SIGNAL PRE-EMPTION), MIAMI, FLORIDA

TABLE 29

OPERATING CHARACTERISTICS ON THE N.W. 7th AVENUE SIGNAL PREEMPTION SYSTEM

		PROJECT/CONDITION			
		N.W. 7th Avenue			
VARIABLE	UNIT	Before	Bus-Only	Before	Bus-Only
Critical Peak Period	—	7 - 9 AM	7 - 9 AM	4 - 6 PM	4 - 6 PM
Length of HOV Lane	Miles	—	9.9	—	9.9
Total Peak Directional Lanes	Lanes	2	2	2	2
Number of HOV Lanes	Lanes	—	0	—	0
Volume - All Lanes	Vehicles	1,461	1,655	1,825	1,905
Volume - Buses	Vehicles	—	23	—	21
Bus/Total Volume	%	—	1.4	—	1.1
Auto Occupancy - All Lanes	PPV	1.30	1.29	1.45	1.41
Person Throughput - All Lanes	Persons	1,895	2,777	2,641	3,221
Person Throughput - Buses	Persons	—	673	—	570
Bus/Total Throughput	%	—	24.2	—	17.7
Speed - Automobile	MPH	21.0	23.0	19.8	23.1
Speed - Bus	MPH	22.7	28.1	20.1	26.8
Travel Time - Automobile	Minutes	28.3	25.8	30.0	25.7
Travel Time - Bus	Minutes	26.2	21.1	29.6	22.2
Violation Rate	%	—	0	—	0

Metric Conversion
1 mile = 1.61 kilometers

this change, all vehicles benefited from this new signal operation. Also, it may be expected that autos received some spin-off benefits in travel speed through signal preemption and increased "green time" for N.W. 7th Avenue.

- The total facility accident rates for both peak periods decreased significantly (statistically) with the intorduction of signal preemption.

Enforcement Characteristics

Chapter 3 presents details on HOV projects related to 1) the enforcement program, 2) the enforcement problems and deficiencies, and 3) the performance of the enforcement program. These enforcement elements are summarized here for the N.W. 7th Avenue project.[10] Signal preemption in itself requires no enforcement above and beyond that required for normal traffic signal operations. The only possible violations requiring enforcement would be 1) unauthorized persons having and utilizing the signal preemption transmitter and 2) motorists unknowingly running the red light because of a change in phasing due to the signal preemption. These violations were never reported on the N.W. 7th Avenue project.

Geometric Standards Related to Enforcement

A signal preemption system does not directly involve geometric design elements. However, a signal preemption may be utilized to assist the egress from a HOV lane. If the terminal treatment is located at a signalized intersection, signal preemption can assist in the exit by providing a bus-lead phase while stopping the conflicting through traffic. In this manner, the bus may accomplish its lane shift maneuvers out of the HOV lane while all other conflicting traffic is stopped.

Traffic Control Related to Enforcement

Traffic control devices used in conjunction with signal preemption preferential treatment involves only traffic signals. Signing, pavement markings and delineators do not affect operation of the signal preemption treatment, unless exclusive lanes are used in conjunction with the preemption system.

Project personnel for the N.W. 7th Avenue bus priority system anticipated several safety problems with signal preemption prior to the project's operation. These safety problems, if they do exist, would require extra attention by enforcement officers. Such safety problems include:

1. Two buses preempting the same signal from two different directions.

2. Bus operators driving with the expectation that he is guaranteed a green signal at the equipped traffic signals.

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10. See section on contraflow lanes in this chapter for detailed information on enforcement of the N.W. 7th Avenue project.

3. Uncertain movements by auto traffic and pedestrians due to erratic and variable cycle and phase lengths caused by signal preemption.

4. Automobiles clustering around the bus in order to receive the benefits of signal preemption.

Overall, the total facility accident rate on N.W. 7th Avenue decreased significantly (statistically) for both AM and PM peak periods with the introduction of signal preemption. Of the four anticipated safety problems, only the clustering of automobiles around the bus was viewed to be a possible problem, although not a severe one requiring special enforcement.

Recommendations for Enforcement

General recommendations on enforcement of HOV priority treatments on arterial streets and highways are presented on page 117. Because there are no direct HOV enforcement requirements associated with the signal preemption priority treatment, there are no specific enforcement recommendations and no need for innovative enforcement techniques.

CHAPTER SIX
INNOVATIVE ENFORCEMENT TECHNIQUES

HOV ENFORCEMENT PROCESS

The enforcement process associated with the operation of an HOV lane consists of a number of interrelated tasks. These tasks include:

1. establish vehicle occupancy[1]
2. establish lane presence
3. record violation
4. address the violator
5. develop optimal deployment scheme
6. promote public awareness of enforcement activities

These tasks are either on-line or off-line activities. On-line activities are directed toward the detection and immediate apprehension of violators of HOV occupancy regulations. Off-line activities serve to enhance the on-line process by providing useful historical information or to reduce the violation rates by public awareness of enforcement campaigns. A functional block diagram depicting the HOV enforcement process is illustrated in Figure 24. The enforcement tasks with potential for the application of innovative techniques are described below.

Establish Vehicle Occupancy. This is one of the two conditions necessary to establish an HOV violation. It is conventionally carried out by enforcement officers traveling on the facility. The presence of the patrol units also serves to promote public awareness of the enforcement activities. Conventional patrols could be supplemented by various photographic techniques, or by civilian observers. As a possible future technique, the registration of carpools could be considered. Such a scheme would probably work best in conjunction with other transportation systems management techniques (parking control, congestion pricing, etc.).

Establish Lane Presence. This is the second condition necessary to establish a violation. It is also normally detected by officers patrolling the facility. Conventional patrols could again be supplemented by photographic techniques coupled with vehicle detectors or civilian observers. Some consideration has been given to the vehicle marking system (VMS) in which one of the vehicle's tires could be marked by a point spray to establish conclusive proof of travel in the restricted lane. However, this technique is not within the current state-of-the art.

Record Violation. Under current enforcement practice, records are kept only of those violators who are apprehended and, due to enforcement difficulties, no data base is generated which is useful for analysis of violation characteristics. The use of civilian observers for recording violations could establish a substantial base of information which could support both on-line (address the violator) and off-line activities (develop optimal deployment scheme). The development of an advanced computerized data base could enhance public awareness of enforcement activities and could, therefore, contribute to reduced violation rates.

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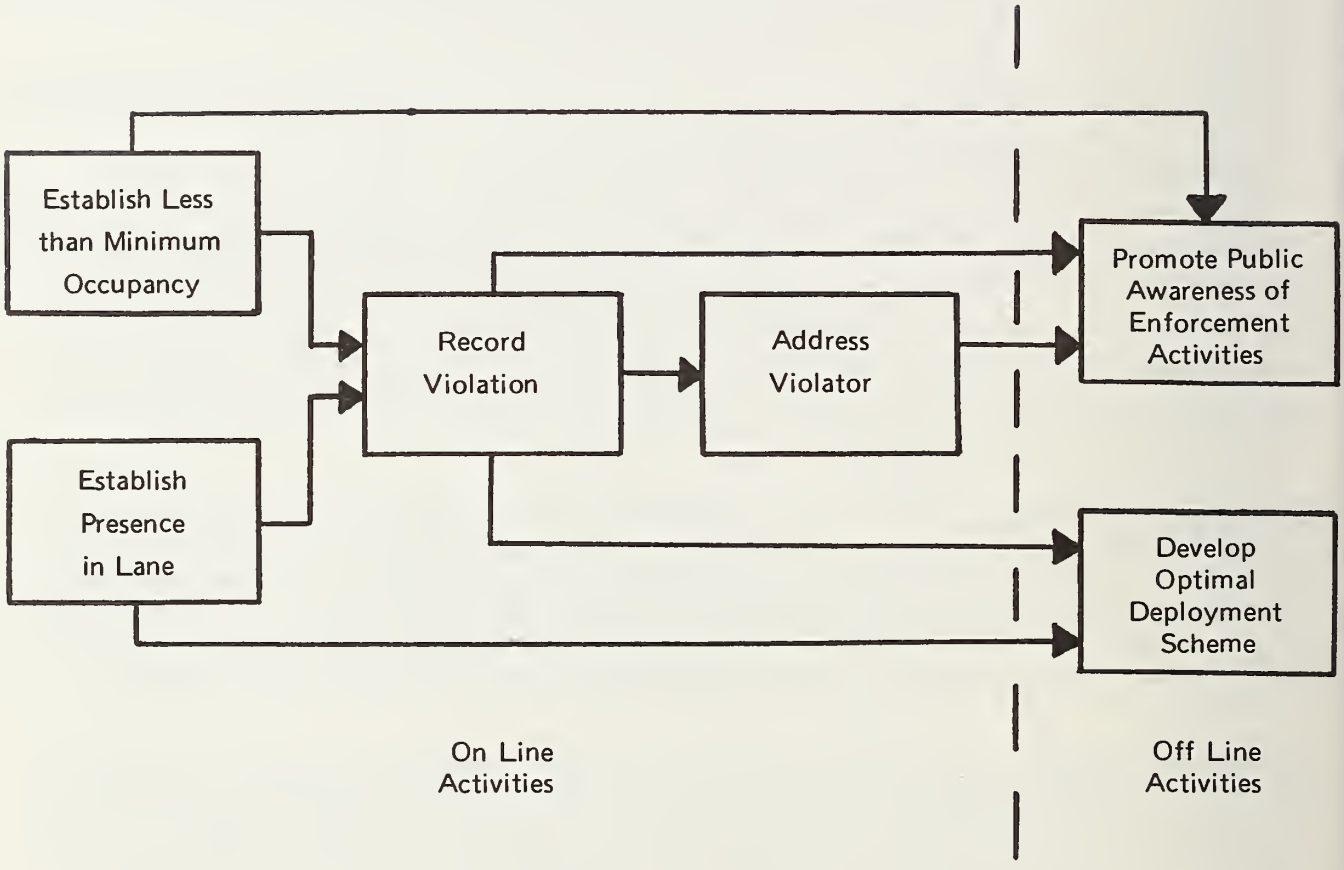
1. This naturally refers to treatments involving carpools. If only buses are permitted to use the HOV facility, the more trivial equivalent task is establish vehicle classification.

FIGURE 24

THE ENFORCEMENT PROCESS



Address the Violator. The usual form of address in this case is a citation or at least an official warning. This is commonly administered immediately upon detection of the violation by the same officer. Many of the proposed innovative detection techniques are aimed at identifying large numbers of violators which would undoubtedly exceed the capacity for conventional apprehension. The conventional form of apprehension can be supplemented by mailing warnings/citations, verbal warnings to habitual offenders, and survey questionnaires to be administered to previously detected violators.

Develop Optimal Deployment Scheme. Conventional enforcement schemes generally rely on random encounters with violators. By analysis of a sufficient quantity of violation data, it is possible that more rational deployment schemes can be developed.

Promote Public Awareness of Enforcement Activities. Public awareness of enforcement activities should provide at least a psychological deterrent against HOV violations. This should be especially true when the enforcement activities are more or less innovative in nature, partly because of the "mystique" involved and partly because of an increased interest from the media. The enforcement techniques should be accompanied by a public awareness campaign.

HOV ENFORCEMENT PROBLEMS AND DEFICIENCIES

A number of geometric-related, operational-related, or institutional-related problems in enforcing the HOV lane occupancy restrictions have been identified earlier in Chapter 3. These problems are mainly associated with 1) determining whether a violation has occurred, 2) apprehending the violator and issuing a citation, and 3) assigning sufficient personnel in an enforcement strategy that will provide adequate enforcement of the HOV lane restrictions. In summary, these enforcement problems are:

Geometric-related problems

1. The lack of a vantage point makes it difficult to witness a violating motorist.
2. The lack of a refuge area makes it difficult to detain a violating motorist.
3. The lack of physical separation between the HOV lane and general traffic lanes increases the opportunities for violations.
4. The lack of a passing zone makes it difficult for the police officer to pursue a violating motorist.

Operational-related problems

1. The determination of the auto occupancy can be very difficult especially on high-speed facilities and in periods of inadequate background illumination.
2. The speed differential between the HOV lane and general travel lanes makes the pursuit of a violating motorist potentially unsafe.
3. A lack of visibility during the issuance of the HOV lane citation may give the impression that the HOV lane restrictions are not being enforced.
4. For certain priority treatments (for example curb bus lanes), a judgement decision may be required by the enforcement officer.

Institutional-related problems

1. The lack of cooperation between operating agency and enforcement agency may compromise enforcement of the HOV lane regulations.

2. Constraints imposed by laws on traffic enforcement may limit the available enforcement strategies.

3. Personnel and funding limitations may result in a reduced enforcement program.

4. A low probability of apprehension coupled with a low fine for the citation may cause many motorists to perceive an acceptable risk in violating the HOV lane restrictions.

INNOVATIVE ENFORCEMENT TECHNIQUES

To find a means to overcome some of the difficulties posed by the "standard" enforcement processes, this research examined various "innovative" techniques that may aid in the enforcement of HOV facilities. These techniques are innovative in the sense that they are not widely used within the context of current traffic law enforcement practice. The techniques that could benefit HOV enforcement include:

1. Use of photographic systems and instrumentation in detecting HOV violations and identifying the violators.

2. Use of law enforcement para-professionals[2] in detecting HOV violations and identifying the violators.

3. Mailing of traffic citations and warning letters to the registered owner (identified through the license plate) of a vehicle violating the HOV facility.

4. Remote apprehension of the HOV violator on an exit ramp or other downstream location by an enforcement officer working in tandem with another officer detecting the HOV violation.

5. Mass screening of license tags to identify habitual violators.

These techniques can be used singularly or in conjunction with each other. For example, photographic instrumentation may be used for photographing license plates and/or auto occupancy. These photos can then be examined by a para-professional, who then prepares citations on violators of the HOV facility for mail-out by the police agency. Each type of arterial and freeway preferential treatment may have a justifiable need for incorporation of one or more of these innovative techniques into the enforcement process.

Later sections in this chapter present state-of-the-art developments regarding 1) the mailing of traffic citations and warning letters to the registered owner of the vehicle violating the HOV facility; and 2) the use of photographic systems and instrumentation in detecting HOV violators.

The use of para-professionals has the benefit of removing the enforcement responsibility from a valuable resource in short supply—the law enforcement officer. The use of such personnel or civilian

2. A para-professional is a trained aide who assists a professional person.

observers for off-line activities, such as data base development, could enhance the efficiency of the on-line process, such as an exit-ramp apprehension campaign.

An exit-ramp apprehension campaign could be based on one officer, who is stationed at a randomly selected off-ramp, receiving identification data (model, color, and license number of vehicle) of violators of the HOV lane restrictions from another officer patrolling the HOV facility. If an identified violator of the HOV lane passes the officer stationed on the exit ramp, apprehension could occur. The selection of the off-ramp, rather than being random, could be based on some type of violation pattern analysis. This analysis would predict the most probable exit ramp and time range for apprehension of habitual violators of the HOV lane restrictions.

A mass screening technique for license tags has been explored recently by the Maryland Motor Vehicle Administration, the Maryland State Police, and the Insurance Institute for Highway Safety.[3] This technique uses a small portable computer which stores information on vehicles which have been involved in certain types of unlawful activity. The data base is utilized by entering the license tag number of each vehicle encountered at an apprehension point. The system responds by indicating whether or not the driver should be detained. This concept could be adapted to HOV enforcement by defining the data base to include only those vehicles identified as repeated (but unapprehended) violators of HOV regulations.

For many of the HOV projects surveyed, changes in law would be necessary prior to the incorporation of any innovative technique listed above into the enforcement process. Certainly, a better understanding of the capabilities of traffic enforcement to execute such techniques within the existing legal environment is highly desirable. Chapter 7 identifies six key legal issues associated with innovative enforcement techniques. Prior to initiating any innovative strategy, local agencies should consult their legal counsel to assess the legal environment in their particular state.

MAILING CITATIONS OR WARNING LETTERS TO VIOLATORS OF THE HOV LANE RESTRICTIONS

This enforcement technique addresses the problems of 1) apprehending the violator and issuing a citation, and 2) assigning sufficient personnel that will provide adequate enforcement of the HOV lane restrictions. The legal environment required to mail HOV citations to the owner of a vehicle violating the HOV facility would exist if two legal concepts—decriminalization and presumption—are included in the jurisdiction's statutes and/or ordinances.[4] Inclusion of these two legal concepts should preclude challenges made against citations mailed to the registered owner. As of the present time, two states (Massachusetts and Texas) have successfully mailed citations to the registered owner of a vehicle for a moving violation. This practice is also wide-spread in Europe.

Two HOV projects have utilized to some degree this enforcement technique of mailing citations or warning letters. The projects are 1) the San Francisco-Oakland Bay Bridge priority lane project, and 2) the Southeast Expressway (Boston) concurrent-flow priority lane project. The San Francisco-based project mailed a warning letter, whereas the Boston-based project mailed a traffic citation.

3. See Miller, A.E., "Summary Report on Project TAGS." A report published by the Insurance Institute for Highway Safety—May 1978.

4. For further information see page 186.

San Francisco-Oakland Bay Bridge priority lane project

This project has been described in detail in the section "Exclusive Toll Plaza Lanes" of Chapter Four. The project utilized the technique of mailing warning letters in conjunction with the introduction of carpools to the HOV lanes. Observers were stationed in the priority lanes at the toll booths and recorded license plate numbers of all lane violators. After the same license plate was observed more than once, the plate number was sent to the Department of Motor Vehicles for identification. About 1 percent of the lane users were constant violators. Letters were then sent to the registered owners of the vehicles informing them of the Vehicle Code violation and indicating that the driver of the vehicle could be apprehended and cited by the California Highway Patrol (see Figure 25). The number of letters sent out at any one time was approximately 7 percent of the daily number of violations. Further observations indicated that the response of the owners to the letter was very good. Only about one violator in ten was observed in the lanes after receiving the letter.[5] While the warning letters did discourage future violations from most of these individuals, they did little or nothing to reduce the overall violation rate. Apparently new violators moved into the HOV lane to replace the removed violators and more direct means of enforcement were considered necessary.

Southeast Expressway (Boston) Concurrent-flow HOV lane

This project reserved the median northbound (inbound) lane for the exclusive use of buses and carpools of three or more persons. The HOV lane operated from 6:30 to 9:30 AM and at all other times the HOV lane was open to general traffic. The length of the HOV lane was eight miles and there was no priority treatment for southbound (outbound) traffic in the afternoon peak period.

The HOV lane was implemented on May 4, 1977, on a voluntary, unenforced basis and operated under that strategy until the HOV lane restrictions were enforced beginning October 18, 1977. As a result of this announced change in enforcement strategy, travel times in the general travel lanes increased and varied from day to day. On November 2, 1977, the project was terminated because of the public outcry and concern by public officials regarding the deteriorated travel conditions in the general travel lanes brought on by the enforcement of the HOV lane.

Enforcement occurred by mailing citations to the registered owners of vehicles violating the HOV lane. About five police officers in vehicles were assigned over the three-hour period per day. Massachusetts General Laws make it possible for a police officer, who upon observing a moving violation and being unable to give the original citation to the violator at the time of the offense, to mail the citation to the registered owner of the vehicle. Massachusetts law further provides that the registered owner of a vehicle shall be prima facie evidence that the owner was the operator at the time of the violation. This mailing procedure was used because police could not apprehend the HOV violator safely at the time of the violation because of the requirement to weave across several lanes of congested traffic. During the 12 operating days of this enforcement program, a total of 1,583 citations were mailed for an average of 132 citations per day (44 citations per hour). On the first day of this enforcement program, approximately 250 citations were issued, whereas by the last day, the number of citations issued decreased to

5. Report on Priority Lane Experiment on the San Francisco-Oakland Bay Bridge, p. 12, State of California Business and Transportation Agency, Department of Public Works, Division of Bay Toll Crossings, April 1973.

FIGURE 25

WARNING LETTER
(San Francisco-Oakland Bay Bridge Project)

A vehicle registered in your name, license number has been observed numerous times in the Car Pool lanes at the San Francisco-Oakland Bay Bridge Toll Plaza without the required number of occupants. The driver of this vehicle has been violating Section 23334 of the State of California Vehicle Code and specifically violating the posted signs delineating toll lanes 8 and 9 for use only by vehicles carrying three or more persons per car. The above vehicle further is in violation of Vehicle Code Section 23302 — "Evasion of Toll."

Continued violation of the posted signs could lead to apprehension of the driver of the above vehicle by the California Highway Patrol and the issuing of a citation for these violations.

This is a warning—not a citation. Please observe the posted signs.

Very truly yours,

Chief Engineer

approximately 50. There has been no accounting of these citations, because once the HOV project was terminated, the court system decided (not on a legal basis) not to hold the persons responsible for the HOV citation. Because of the short time period for the mailing of citations, it was not possible for any legal challenges of this enforcement procedure to occur.

The before violation rate (percentage of vehicles in the HOV lane that had one or two occupants) was 85 percent before the program and the rate decreased during the program to 35 percent in the peak period and 23 percent in the peak hour. The peak hour HOV lane volume decreased from 1,466 vehicles in the before period to 522 vehicles in the after period. This decrease coupled with a corresponding increase in the general lanes volume caused the peak hour travel time in the general lanes to increase from 17 to 24 minutes from the before to after condition.

These changes do not necessarily reflect the singular impact of mailing of citations, but rather the impact of moving from voluntary (zero) enforcement of the HOV lane to strict enforcement. Clearly, the use of the mail-out enforcement technique, as contrasted to conventional enforcement, provided for higher productivity and less disruption to the traffic flow. Five police officers comprised the mail-out enforcement program and issued a one-day high of 250 citations during the three-hour peak period. For this same three-hour time period and assuming 15 minutes per citation, it would take nearly 21 officers to issue 250 citations using standard enforcement techniques. In actual operation, 21 officers using the standard enforcement technique could not be assigned to HOV lane enforcement because of the potentially massive disruption in traffic flow that might occur. It has been estimated that the percentage of HOV lane violators receiving a citation by the mail-out enforcement technique using five police officers ranged from 20 to 40 percent. Five police officers using the standard enforcement technique would be able to issue a maximum of 60 citations per peak period, which on the first day of the enforcement period would have only accounted for approximately 5 percent of the HOV lane violators.

USE OF PHOTOGRAPHIC SYSTEMS AND INSTRUMENTATION IN DETECTING HOV VIOLATORS

This enforcement technique addressed the problem of 1) determining whether an HOV lane violation has occurred, and 2) assigning sufficient personnel that will provide adequate enforcement of the HOV lane restrictions.

The courts have recognized that photographs may be relevant to the issues and may be introduced as evidence to establish identities. Foremost among the legal concerns of this issue are 1) invasion of privacy, 2) expert witness testimony, and 3) confidentiality and destruction of photographic records.[6]

Two separate research projects sponsored by the United States Department of Transportation have studied photographic instrumentation for enforcement purposes. These projects are 1) the Mobile ORBIS III Speed Enforcement Demonstration Project in Arlington, Texas[7], and 2) a Photographic System

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6. For further information, see page 189.

7. Dreyer, Charles B. and Hawkins, Thomas E., Mobile ORBIS III Speed Enforcement Demonstration Project in Arlington, Texas, Final Report, Submitted to National Highway Traffic Safety Administration, Department of Transportation (Contract No. DOT-HS-346-3-692), 1976.

for Obtaining Auto Occupancy Counts.[8] The Federal Highway Administration is presently extending this latter research in part to produce a photographic system specifically for the various needs associated with enforcement of HOV facilities.

Mobile ORBIS III Speed Enforcement Demonstration Project in Arlington, Texas[9]

This project consisted of a mobile van having a photomechanical device known as ORBIS III. Using infrared film, ORBIS III could photograph in a single frame the driver's face and the vehicle's front license plate as well as record speed, time and date on the photograph. The device has been used in New Jersey and Texas and in the latter state, speeding violations were then issued to the registered owner of the vehicle. Preliminary results indicated it may have a potential for achieving a reduction in speeders on ORBIS III monitored roadways. An administrative evaluation of the project showed the mobile ORBIS III unit to be less cost-effective than standard patrol techniques; however, the cost-effectiveness of the unit could be improved considerably through design and operation of appropriate patrol strategies.

Photographic System for Obtaining Auto Occupancy Counts

The objective of this research was to develop, assemble, and test a photographic system which could be utilized by state and local transportation agencies to obtain auto occupancy counts as well as other information related to person and vehicle movement. In the development of this system, the following guidelines were followed.

1. Whenever possible within funding and time limitations, use off-the-shelf, commercially available hardware.

2. The system should have wide application other than the specific use for which it is intended.

3. The system shall be operable by relatively untrained, non-photographic personnel.

This photographic system consists of a camera, a stroboscopic light source and a vehicle-actuated triggering mechansim. Figure 26 shows this system. Guidelines for applying photography to HOV enforcement are presented on the following pages and are based largely on the preliminary results of this photographic research and on discussions with the personnel involved in the research.

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8. Naval Surface Weapons Laboratory, Photographic System for Obtaining Auto Occupancy Counts, Technical Report, Submitted to Federal Highway Administration (Office of Highway Planning), Department of Transportation, 1978.

9. For further information on this project, please see pages 194 and 197.

FIGURE 26

FHWA/NSWL PHOTOGRAPHIC SYSTEM FOR OBTAINING AUTO OCCUPANCY COUNTS
(under revision)

CONSIDERATIONS FOR APPLYING PHOTOGRAPHY TO HOV ENFORCEMENT

The Federal Highway Administration is currently conducting research into the capabilities and limitations of photographic techniques in the determination of vehicle occupancy.[10] Under this research program, a prototype photographic surveillance system, consisting of a camera, a stroboscopic light source, and a vehicle actuated triggering mechanism have been developed by the Naval Surface Weapons Laboratory (NSWL) of Dahlgren, Virginia. The guidelines which are presented here are based largely on the preliminary results of this photographic research and on discussions with the NSWL and FHWA personnel involved in the research.

The guidelines will follow the following outline:

I. Application of photography to HOV enforcement

- A. Identifying violating vehicles
- B. Obtaining evidence of a violation
- C. Studying violation patterns

II. Operational Requirements

- A. Vantage point
- B. Ambient conditions
- C. Security, theft and vandalism
- D. Hidden passengers
- E. Vehicle design differences
- F. Motorist Evasion

III. Camera Requirements

- A. Camera format
- B. Lens focal length
- C. Shutter and apperature considerations
- D. Data chamber
- E. Projector
- F. Camera aiming
- G. Light source
- H. Filters
- I. Environmental housing and protection
- J. Camera activation

IV. Film requirements

V. Costs

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10. Naval Surface Weapons Laboratory, Photographic System for Obtaining Auto Occupancy Counts, Technical Report, Submitted to Federal Highway Administration (Office of Highway Planning), Department of Transportation, 1978.

APPLICATION OF PHOTOGRAPHY TO HOV ENFORCEMENT

There are three areas in which photography may be applied to the enforcement of HOV regulations. These include 1) identifying violating vehicles for subsequent enforcement purposes, 2) obtaining suitable evidence of a violation, and 3) studying violation patterns.

Identifying Violating Vehicles

One of the major problems in HOV enforcement is the difficulty of detecting a violation and identifying the violator. This is particularly true on major expressways where there may not be a convenient vantage point from which to detect a violator. A less-than-favorable vantage point may cause traffic congestion, delay and safety hazards.

A photograph of the vehicle, showing both the license tag and a sufficient view of the interior could conceivably provide an adequate basis for issuing such a citation. The use of photography in this case could make the detection process less conspicuous to the motorist, and the apprehension process less disruptive to traffic. It could also reduce the police manpower requirements and provide a permanent record of the violation.

Obtaining Evidence of a Violation

If any form of delayed apprehension is employed, or when the apprehending officer is acting on the basis of information supplied by an upstream observer, the conviction of the violator may depend on the ability to produce concrete evidence of the fact that the violation took place. A photograph of the offending vehicle could produce such evidence. In this case, it should not be necessary to actually identify the number of passengers within the vehicle since that information could be established adequately at the time of apprehension. A simple photograph of the vehicle and its license tag traveling in the HOV lane should be sufficient for enforcement purposes. It would also be beneficial if the photograph could have imprinted the date and time of day.

Studying Violation Patterns

Current enforcement activities are based generally on a direct response strategy in which a citation is issued upon detection of an offense. The effectiveness of this type of enforcement could possibly be improved through a program of surveillance to determine where and when violations are most likely to occur. A study of violation patterns could also be used in evaluating the effectiveness of a particular enforcement program or strategy. Photographic techniques could be especially productive in this area since a substantial quantity of photographic data could be acquired at a relatively low cost.

OPERATIONAL REQUIREMENTS

For the most part, the problems encountered with the use of photography will not preclude the use of photography altogether, but will limit the amount and usefulness of the data which may be ob-

tained under certain conditions. Fortunately, in HOV enforcement, it is not necessary that any technique be 100 percent successful in terms of its ability to detect and apprehend offenders. In several HOV priority projects, the enforcement agencies have conceded, more or less publicly, that there is a very small probability that an offending motorist will be apprehended. This leads to substantial violation rates for the project. In this circumstance, any technique which would increase the probability of apprehension to a level perceivable by the motorist should have a beneficial effect on the degree of violations. Even with a fairly low probability of apprehension on a single trip, virtually all of the habitual violators would be apprehended occasionally.

Vantage Point

To employ photography effectively, a suitable vantage point must be available for setting up the equipment. An average distance of 50 feet (15 m) should be maintained between the camera and the vehicle when the photograph is taken. This could pose problems on facilities where accessibility to the median is limited or where an adequate median simply does not exist. The FHWA/NSWL research has yet to determine whether it is possible at the same vantage point to photograph both the license plate and auto interior. In states where only rear license tags are required, it is presumably even more difficult for one vantage point to suffice. In lieu of one vantage point, it may be possible to utilize a two-camera synchronized system.

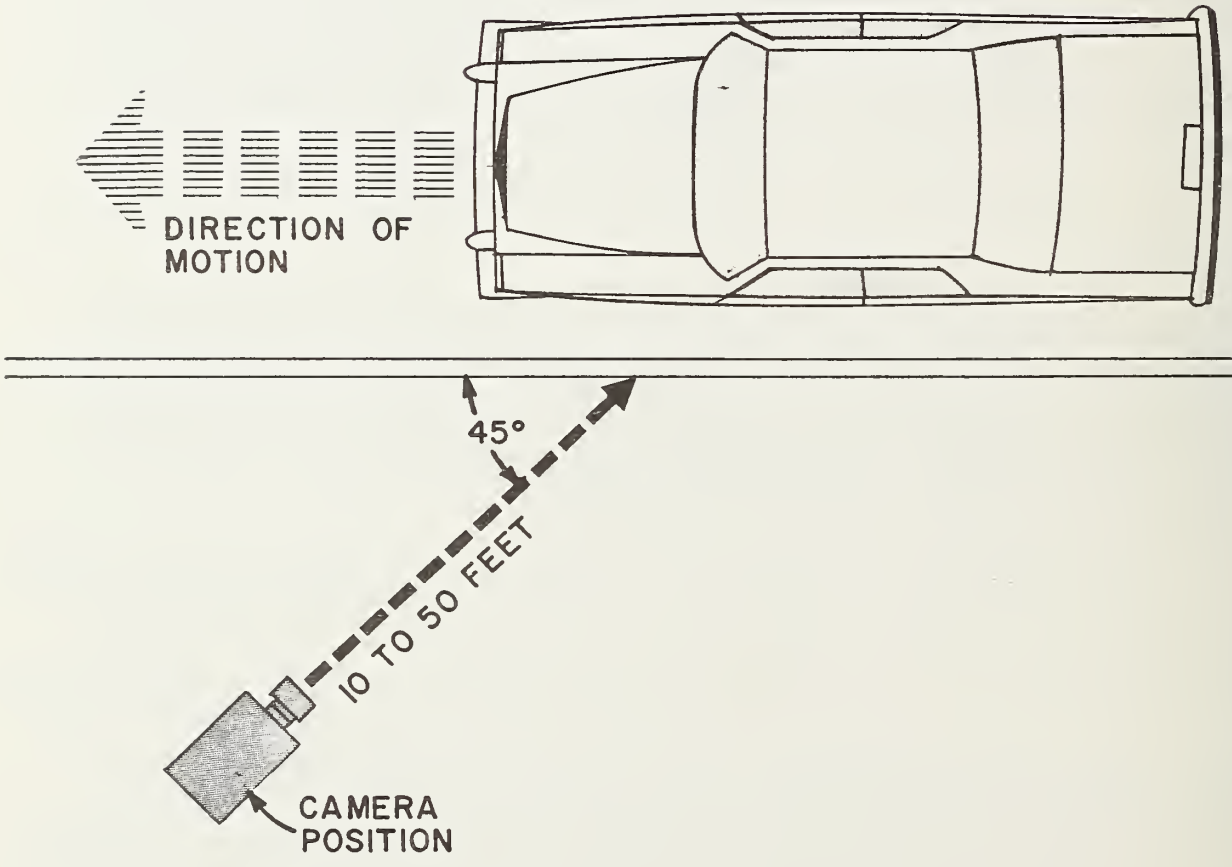
Photographing the license tag only is not a difficult problem. Obtaining an adequate photograph of the front seat of the vehicle is also feasible under most conditions. However, producing a clear image of the entire interior of the vehicle (both front and rear seats) is a rather difficult process and a fairly low success rate can be anticipated. This suggests that photographic techniques are best suited to facilities where a substantial number of violators are single occupant vehicles.

It has been found that the best viewing angle for interior photography is approximately 45 degrees from the longitudinal axis of the vehicle and on the same side as the driver as illustrated in Figure 27 . The camera should be aimed at the side post of the windshield. This tends to obscure the view of the driver because of the side post but it improves the view of the passenger side. This is the optimal strategy for HOV enforcement because the presence of the driver may be taken for granted and the presence or absence of the passenger is the main item of interest. This viewing angle also minimizes interference of the front seat headrest to the view of the rear passenger seat. A clearer view of the rear seat occupancy is obtained through the side windows, but this tends to obscure the view of any front seat passengers. The side view may be preferable when the carpool definition requires a large number of passengers and an empty rear seat would be considered as a strong indication of a violation.

The vertical angle is not particularly critical, although the best vantage point appears to be approximately the same level as the driver's head (i.e. about four feet (1.3 m) above the ground). Distance from the vehicle is not particularly important either. The NSWL light source (see section on light source) was developed to illuminate the inside of the vehicle and designed for use at distances of approximately 50 feet (15 m) from the vehicle. If much shorter distances are to be used, the brightness of the light source can be reduced so as not to be offensive to the driver.

FIGURE 27

VIEWING ANGLE FOR INTERIOR PHOTOGRAPHY



METRIC CONVERSION

1 ft = 0.3 m

Ambient Conditions

Ambient conditions are not especially critical in photographing the license tag. Adequate images may be obtained over the range of illumination normally encountered from sunrise to sunset on both sunny and cloudy days.

The interior passenger compartment view required for occupancy counts needs an external light source such as that developed by NSWL (see section on light source). The best images are obtained under overcast conditions when sky glare from the windshield and other glass is minimized. Sky glare can be eliminated completely by photographing under an overpass, however, the flash of the light source could be distracting to the motorist in this reduced light level.

Inclement weather (fog or rain) or extreme temperature do not appear to degrade the photographic image to any significant extent.

Security, Theft and Vandalism

The problems of security, theft and vandalism will depend on the conspicuousness of the equipment, which in turn will depend on the purposes for which the photographs are being taken. If the results are to be used primarily for evaluation purposes, the equipment should be well hidden to avoid biasing the sample. On the other hand, the maximum impact on violation rate is likely to be obtained when the equipment is placed conspicuously within view of the motorist. The magnitude of this problem is difficult to determine. It is suggested however that some anti-theft measures may be deisrable, especially if the equipment is to be unattended. Conspicuity can also be enhanced through extensive news media coverage.

Hidden Passengers

The minimum carpool definition requirements do not state that all passengers must be visible from the exterior of the vehicle. The suitability of photographic evidence may, therefore, be questionable in some jurisdictions due to the possibility of the actual or ficticious presence of infant children or sleeping passengers. The use of legislative mechanisms to overcome this problem is discussed on page 194.

Vehicle Design Features

The vehicle design features which may prove troublesome from a photographic point of view include: window curvature (which can cause both reflective and refractive problems), small side windows, or no side windows on vans, high head rests and seat backs, and reflective material installed to reflect solar radiation. In many cases, these design features create an equal degree of difficulty for the manual observer and are therefore not peculiar to photographic techniques. It must be recognized therefore, that due to vehicle design, some violators will escape apprehension.

Practically all vehicles are designed with some degree of window curvature. Preliminary experience with the NSWL system suggests that the curvature of the front windshield does not create a pro-

blem in a significant number of cases. On the other hand, when photographs are taken from the rear of the vehicle to obtain license tag information, it is frequently impossible to obtain meaningful information through the rear window because of its curvature.

Motorist Evasion

Conspicuously placed photographic equipment on line-haul HOV unrestricted entry/exit systems of some length can be easily evaded by offenders by simply exiting the lane in the vicinity of the camera and re-entering immediately downstream of the field of view. This maneuver could pose serious safety implications unless sufficient delusive or "fake" installations accompany the operative camera to make such maneuvers undesirable.

CAMERA REQUIREMENTS

There is a wide range of photographic equipment available for HOV enforcement applications. In general, this equipment may be categorized according to the market for which it is intended. The market categories are identified as follows:

- consumer/hobby
- professional/industrial
- instrumentation
- advanced scientific
- military/covert

The requirements of HOV enforcement applications suggest that the instrumentation quality equipment is the appropriate choice. Instrumentation quality cameras are generally supplied with the standard "C-mount" lens for interchangeability. The lower cost equipment designed for the high volume markets does not generally provide the degree or ruggedness, dependability and flexibility required for this particular application. The features found in advanced scientific equipment, such as high frame rates, special use optics, etc., are extremely expensive and are of no particular value to HOV enforcement. While it is probable that some useful techniques could be drawn from the military/covert area, these techniques are generally not available for civilian applications.

Camera Format

Three format choices are available: eight millimeter, sixteen millimeter and thirty-five millimeter. The 16 millimeter format has been found to produce adequate resolution for all HOV enforcement purposes, including license tag reading and occupancy counting. The image quality available with 8 millimeter film is not suited to detailed single frame analysis. The 35 millimeter film produces a superior quality image but the camera film and film processing costs are considerably higher than the 16 millimeter equipment. The 16 millimeter camera is used mainly for photologging purposes and the availability of this equipment should be taken into consideration. As a general rule, the recommended type of camera is unlikely to be found in a camera shop, but could be purchased as a stock item from any of several distributors who deal in instrumentation quality equipment.

Lens Focal Length

A 75 millimeter (telephoto) lens should be used for filming distances in the range 50-60 feet (15-18 m). Where median dimensions require smaller filming distances in the range of 20-25 feet (6-7.5 m), a 25 millimeter lens would be more appropriate. Twenty-five millimeters is considered a "standard" lens for the 16 millimeter format.

Shutter and Aperature Considerations

In order to produce images which are sharp enough for HOV enforcement purposes, shutter speeds of 1/250 to 1/500 second, or faster, are required. The normal shutter speed on a commercial camera is 1/40 second. Instrumentation quality equipment may have ultra fast shutter speed and precision optics. The data required to determine minimum shutter speed as a function of vehicle speed is contained in the following formula for amount of image motion (blur):

$$\text{Image Motion (inches)} = 12(t)\,(v)\,(\sin \theta), \text{ where}$$

- t is shutter speed of camera in seconds (decimal)
- v is velocity of subject in feet/second
- θ is angle of direction between lens axis and direction of motion (θ can be 0 to 180 degrees)

This relationship is illustrated for a range of vehicle and shutter speeds in Figure 28. Because of the variation in ambient light conditions, the camera should be provided with an automatic exposure control feature. This feature should be "shutter preferred" in which the aperature is varied automatically in response to varying ambient light levels rather than "aperture preferred" in which the shutter speed is varied.

Data Chamber

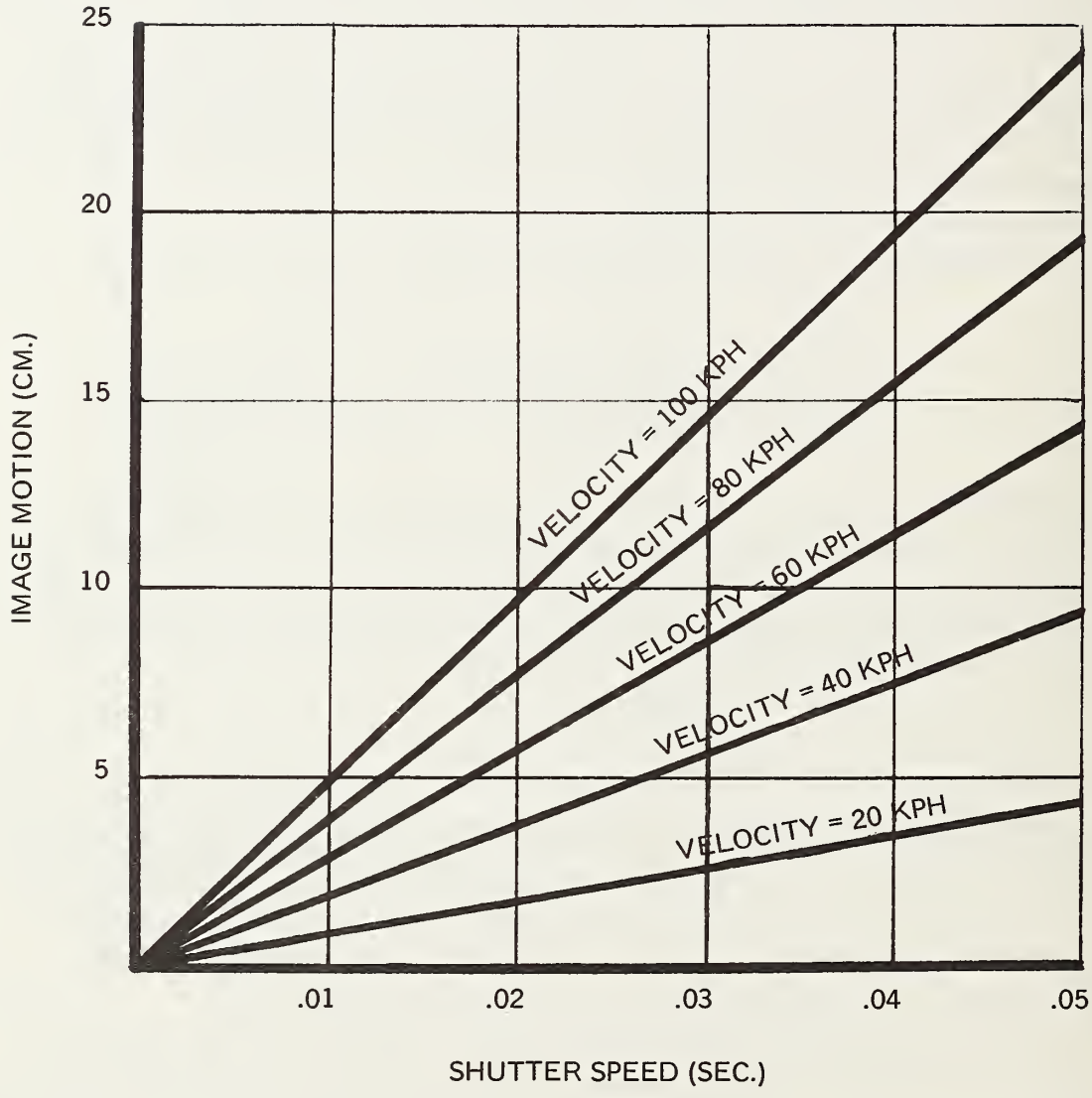
For most HOV enforcement purposes a data chamber on the camera will be required to indicate on the film the date, time, location, and perhaps some other pertinent data. Data chamber requirements must be specified at the time of purchase. The data may be displayed on the film either vertically or horizontally. Data which is displayed vertically may be located either within the frame of the film or between the sprocket holes. Data displayed horizontally must be within the film frame.

Projector

The main requirements of the projector is that it be compatible in all respects with the camera equipment and have the single frame advance feature. Particular attention must be given to the data display technique of the camera. Data which is displayed either vertically or horizontally within the film frame can be accommodated by a standard projector. On the other hand, data displayed vertically between the sprocket holes will require a special projector with an enlarged field of view.

FIGURE 28

IMAGE MOTION DETERMINATION
(Angle Direction (e) is 10^{o})



Metric Conversion

1 inch = 2.5 centimeters
1 mile = 1.61 kilometers

The optical quality of the projector is also an important consideration. The optical quality of an instrumentation grade projector is generally higher than that of a commercial/industrial unit. This can be important in such areas as reading the license tag numbers but is also especially important from an operator fatigue point of view. It must be remembered that all photographs taken in the field must be subsequently analyzed manually on a frame by frame basis and the productivity of the analyst will be influenced considerably by the quality of the image. An instrumentation quality projector is superior to a standard commercial/industrial projector in that the former has 1) an optical system which does not degrade the quality of the image in single frame advance, and 2) a superior shutter design which eliminates any flickering image effect.

Camera Aiming

Instrumentation quality cameras are not normally supplied with an aiming mechanism and this feature must usually be ordered as a separate accessory. The options are as follows (in order of cost from low to high):

1) no aiming mechanism — this would require that the camera be oriented in an approximate and subjective fashion by the operator.

2) bore sight — this option allows the operator to view the image directly through the lens prior to installing film. It is a cumbersome technique and generally suited to applications involving long term installation of the camera with a specific orientation.

3) external view finder — this accessory is mounted on the camera and provides an approximate indication of the field view which may be expected on the film.

4) "through the lens" reflex view finder — this is the most precise and easiest to use alternative but adds significantly to the cost of the equipment.

Light Source

No external light source is required for photographing license plates under daylight conditions (sunrise to sunset), however one is required during darkness. When interior photographs are being obtained for vehicle occupancy counting, it is necessary to provide some type of external illumination from a stroboscopic flash unit regardless of the ambient conditions. There should be a less than ten degree angle between the camera and the strobe unit (see Figure 27).

The standard commercial/industrial equipment available for this purpose has been found to be inadequate for two reasons: one, the emitted light beam is not sufficiently concentrated to provide the required degree of intensity, and two, it does not meet the requirement for continuous repetitive recycling.

For these reasons, a special light source was developed by NSWL which provides a high intensity focused beam and the capability for recycling continuously at three second intervals. Testing of this unit under operational conditions is currently in progress. One concern is the extent of motorist distraction caused by the stroboscopic flash. This strobe unit does have a filter unit to reduce its intensity.

Filters

The recommended film requires no filtering for color compensation or haze reduction, however, a red polarizing filter should be used for reduction of glare from the vehicle's windows. The external light source is not polarized and will cause no additional glare provided that the light source is located no further than ten degrees from the viewing angle of the camera.

Environmental Housing and Protection

The camera should be enclosed in an environmental housing for protection against wet and freezing weather. Several types of housing are available commercially for this purpose. These housings are intended primarily for television surveillance applications and a wide variety of options are available, such as windshield wipers, remote controls, etc., which may not be required for HOV enforcement purposes. If the enforcement application is intended to be highly conspicuous to the motorist, it may be desirable to purchase several environmental housings for permanent or semi-permanent installation along the roadway. The photographic equipment can then be transferred periodically between the various housings. This may enhance the deterrent effect of the enforcement activities.

Camera Activation

The camera may be activated either manually or automatically and either directly or by remote means. Manual activation would normally be employed if the violation has already been detected and the photograph is being taken to obtain evidence. Automatic activation would be required at locations where unmanned operations are planned. Methods of automatic activation include tape switches or road tubes attached to the roadway, various types of standard vehicle presence detectors, or possibly an innovative optical detection method developed in connection with the NSWL project.

FILM REQUIREMENTS

Black and white film is preferred over color film for most applications because of its lower cost. The NSWL system achieved its best results with "linagraph-shellburst No. 2476" film from Eastman Kodak.[11] This is a high resolution, medium contrast film with an exceptionally high exposure latitude and a nominal ASA rating of 200. The ASA rating can be varied substantially during the processing of the film. This is a sole source item but is readily available from film suppliers. The film is equally effective when used for photographing the license plate or the interior of the vehicle.

Film usage should be calculated at the rate of 40 exposures per foot of 16 millimeter film. The negative image on the black and white film is of an adequate quality for analysis, both in reading license plate numbers and in counting passengers. There is no need to convert to positive images.

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11. The specification number is SGE-430; the catalogue number is 1714021; the price of a 125-foot roll (16 mm) is $5.67/roll.

COSTS

Equipment and material costs may vary between agencies due to purchase quantities, procurement methods, and other factors. The following cost guidelines are offered for budgetary purposes based on 1978 figures.

Item	Cost
1. camera (complete)	$5,000*
2. projector	$2,000
3. environmental housing	$ 300
4. light source	unknown
5. film - purchase	$5.67/125 foot roll
6. film - processing	10 to 30 cents per roll

*depends on optional equipment

CHAPTER SEVEN
LEGAL ISSUES

IDENTIFICATION OF LEGAL ISSUES

For many of the HOV projects which were surveyed, changes in law are necessary prior to the incorporation into the enforcement process of any innovative technique presented in chapter 6. Certainly, a better understanding of the capabilities of traffic enforcement to execute such techniques within the existing legal environment is highly desirable. This research has identified six key legal issues associated with the innovative enforcement techniques (see Table 30).

1. Can photographic evidence be made to be admissable in traffic court through legislative action?

2. If instrumentation is used in the enforcement operations, what type and amount of instrument certification would be required?

3. Can the minimum number of occupants required for the utilization of an HOV lane be related to their visibility without being successfully challenged on the basis of age discrimination (i.e. small children) or other grounds?

4. Can citations be mailed out to the owner of a vehicle for a moving violation without the driver's identification being confirmed?

5. Can a non-witnessing officer cite a violator of an HOV facility?

6. Do the legislative requirements for effective HOV lane enforcement require the allocation of powers to the enforcement agency which can then be abused? What can be done to minimize this possibility?

REVIEW OF LEGAL ISSUES

Legal research for this project was conducted through a survey of state statutes, municipal ordinances and regulations, and state and federal case law. References were made also to other traffic studies and to legal texts, including American Law Reports and American Jurisprudence.

In order to fully comprehend the legal issues, there are several legal concepts that are prominently involved. The legal concepts are (1) prima facie evidence, (2) presumption clause and (3) decriminalization.

Prima Facie Evidence

This is legal evidence adequate to establish a fact or raise a presumption of fact unless refuted. Legislative bodies must provide, by statute or ordinance, that certain facts shall be prima facie evidence

TABLE 30

LEGAL ISSUES APPLICABLE FOR INNOVATIVE ENFORCEMENT TECHNIQUES

LEGAL ISSUE	ENFORCEMENT TECHNIQUE			
	Photographic Instrumentation	Para-Professional	Mailing of Citation	Tandem Patrol
1. Admissibility of photographic evidence	x			
2. Instrument certification requirements	x			
3. Visibility of occupants	x			
4. Mailing of citation to owner of vehicle	x	x	x	
5. Non-witnessing officer issuing the citation	x			x
6. Allocation of powers to the enforcement agency	x	x	x	x

of other facts. Such a provision is valid if there is some rational connection between the fact proved and the ultimate fact to be established.[1] In regard to prima facie evidence, it is up to the defendant to refute the evidence. The establishment of prima facie evidence through legislative enactment benefits the enforcement officer by putting the burden of proof on the defendant and not the officer. Prima facie evidence eliminates a "false arrest" claim against the officer by allowing for a rational connection between a proven fact and the ultimate fact to be established.

For an HOV project, a potential area of prima facie evidence (assuming appropriate legislative statutes/ordinances have been passed) could be that the registered owner of a vehicle violating the HOV facility is the same person driving the vehicle at the time of the violation. The fact that a vehicle was violating the HOV restrictions could be enough proven fact to establish the registered owner as the person operating the vehicle. This presumption makes the registered owner responsible and it is then up to the owner of the vehicle (defendant) to refute this connection if it is not valid.

Presumption Clause

This refers to the legal wording in a legislative statute or ordinance whereby prima facie evidence is legally accepted. Presumptive evidence and prima facie evidence are synonymous terms that are used interchangeably. The presumption clause is a violation of the Fourteenth Amendment due process only if it creates an inference that is given the effect of evidence to be weighed against the opposing testimony.[2]

1. 29 American Jurisprudence (Am. Jur.) 2d, Evidence § 4.

2. 29 American Jurisprudence 2d, Evidence, § 10.

Decriminalization

A legislature may reduce traffic violations and/or safety equipment violations from criminal offenses to civil (non-criminal) offenses or it may just remove jail as a sanction for such offenses. This process is called "decriminalization." A parking violation is one traffic-related offense that is almost universally considered a civil offense. It is not uncommon for non-hazardous moving traffic violations as well as certain speeding violations also to be decriminalized. Excessive speeding, moving violations which result in death, personal injury or a specified amount of property damage and violations which may result in suspension or revocation of a driver's license may still be afforded different legal treatment than decriminalized traffic offenses.[3]

The effect of decriminalization eliminates many of the due process requirements associated with a criminal offense and by doing so expedites the processing of traffic infractions. Individual rights that the accused shall have in a criminal prosecution that may be affected by decriminalization include 1) the right to a speedy trial, 2) the right to counsel, 3) the right to confrontation, 4) the right to be informed as to the nature and cause of the accusation and 5) the right to go free unless the state can prove all elements of the crime charged, beyond a reasonable doubt.[4] It cannot be doubted that the rights granted a criminal defendant impose substantial burdens on the state. Decriminalization represents one technique employed by legislative bodies to escape these burdens. One practice has been to change the labels of the statutes under which individuals are prosecuted from criminal to civil. However, a legislative declaration that a violation is noncriminal will not necessarily preclude scrutiny by the court.[5]

A person charged with a traffic infraction, or in other words a non-criminal offense, may be given several choices. These may include: (1) paying the civil penalty (as described by law and it can include monetary fines, "points" assessed against the driving record, license suspension, and attendance at driver improvement school.); (2) forfeiting bond in an amount equal to such penalty, thus waiving the right to appear for a hearing; or (3) electing to appear for a hearing at which time the occurrence of the offense must be proved, depending on the type of legal proceedings, by a preponderance of the evidence or beyond a reasonable doubt. Appeal of the verdict may be allowed.[6]

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3. Florida Statutes § 318.19.

4. Argersingle v. Hamlin, 407 U.S. 25 (1975).

5. If a "change of label" does not constitute effective decriminalization, it must be determined what is sufficient. A review of a recent Oregon Supreme Court decision indicates what factors must be considered. In Brown v. Multnomah County District Court, 280 Or. 95, 570 P. 2d 52 (1977), the court held unconstitutional certain amendments to the Oregon vehicle code purporting to decriminalize the offense of driving under the influence of intoxicants. ORS 484.365. Rights excluded under the code included the right to counsel, right to trial by jury, and the right to require the state to prove its case beyond a reasonable doubt. In making its determination whether the civil penalty proceeding remained a criminal prosecution for constitutional purposes, the court examined five criteria: 1) type of offense, 2) nature of the penalty, 3) collateral consequences, 4) punitive significance, and 5) enforcement practices. The court concluded that the code's offense of driving while under the influence of intoxicants, and its enforcement and punishment, retained too many penal characteristics not to be a criminal prosecution with respect to constitutional guarantees.

6. Florida Statute § 318.14 (4) & (5).

One of two types of legal procedures—adminstrative or criminal—as specified in the law of each jurisdiction may be associated with a traffic infraction resulting in possible differences in statutory language. "Complaints" may be issued where the procedure is administrative, in contrast to issuance of "citations" where the procedure is criminal. Similarly, the state's burden of proof may be only a "preponderance of the evidence" for administrative procedures in contrast to "beyond a reasonable doubt" for criminal procedures. Preponderance of evidence, according to one explanation, means evidence which is of greater weight, or more convincing, than that which is offered by the opposing party.[7] A state may retain criminal procedures for handling traffic infractions in order to preserve certain basic individual rights such as relating to burden of proof.

Because of the elimination of the due process requirements, a jurisdiction may not favor decriminalization. Decriminalization requires a reorientation and reorganization of the systems of regulation of poor driver behavior from a criminal orientation to a civil and administrative orientation for such a change to be fully effective. Of the various methods now employed to process traffic violations, the most cost-efficient method, as based on several research studies and demonstration projects, is the non-criminal, traffic infraction approach using administrative procedures.

The remaining sections of this chapter examines the legal environment associated with each of the six legal issues.

ADMISSIBILITY OF PHOTOGRAPHIC EVIDENCE

Courts have recognized that photographs may be relevant to the issues and may be introduced as evidence to establish identities. Foremost among the legal concerns of this issue are (a) invasion of privacy, (b) right to equal protection, (c) freedom of association, (d) photographs as evidence, (e) expert witness testimony and (f) confidentiality and destruction of photographic records.

Invasion of Privacy

HOV photographs may be challenged as an unconstitutional invasion of privacy. Attorney Generals of several states (Texas, South Carolina, Michigan, Nevada and Arizona) have ruled that there is no actionable invasion of the right of privacy based on photographs taken by enforcement authorities of persons traveling the public highways. These rulings were based on the conclusions that a person driving on public highways subjected himself to public view and it is reasonably within the state's police power to promote public safety in photographic methods of speed enforcement.[8] In addition, the United States Supreme Court has recognized the constitutional right to personal

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7. 32A C.J.S. Evidence § 1021.

8. Attorney General of Texas, Opinion No. M-692, 1970.
State of Texas vs. James Reeves; County Criminal Court No. 3 of Tarrent County, Texas, 1973.
Dreyer, Charles B. and Hawkins, Thomas E., Mobile ORBIS III Speed Enforcement Demonstration Project in Arlington, Texas, Final Report, Submitted to National Highway Traffic Safety Administration, Department of Transportation (Contract No. DOT-HS-346-3-692), 1976, pp. 31-32.

privacy in the areas of procreation, raising of children and family living arrangements,[9] but it has hesitated to extend it much further.

Right to Equal Protection

The photographic equipment may not be able to check every vehicle in the HOV lane for such reason as some vehicles like panel vans cannot be looked into easily, or the photographic equipment is recycling. These limitations may give rise to a claim that there is a denial of equal protection. It has been pointed out, however, that this is similar to any policeman who cannot stop all violators on the road. That has never been grounds for reversal of a traffic conviction.[10]

Freedom of Association

It might also be claimed that photographic surveillance "chills" the exercise of First Amendment rights of association. Someone might choose not to ride with another rather than risk being photographed together. The Supreme Court has stated, "Allegations of a subjective 'chill' are not an adequate substitute for a claim of specific present objective harm or a threat of specific future harm."[11] Under this reasoning, a defendant would have to show that photographs were or would be used to interfere with his right to associate with others. Since the photographs are not taken to keep track of who the driver is with, it would be difficult for anyone to show present or future specific harm.

Photographs as Evidence

Photographs, when offered as evidence of the person(s) photographed, must be supported by the testimony of a qualified witness.[12] Such a photograph must be duly verified to be admissible as evidence. It may be admitted as either (1) an illustration of the witness' testimony or (2) as a "silent" independent photographic witness. It must first, however, be made a part of some qualified person's testimony. Generally, photographs are admissible as evidence as direct evidence of things which have not been directly described by a witness as having come from his observations.[13]

Authentication or verification is necessary for a photograph to be admissible in evidence. An HOV photograph would have to be shown to be a substantially true, accurate and faithful

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9. Roe v. Wade, 410 U.S. 113 (U.S. Supreme Court 1973).
   Moore v. City of East Cleveland, 97 S. Ct. 1932 (U.S. Supreme Court 1977).
   Paul v. Davis, 424 U.S. 693 (U.S. Supreme Court).
10. 7 Urban Lawyer 115 at 122.
11. Laird v. Tatum, 408 U.S. 1 (1972), p. 13-14.
12. 29 Am. Jur. 2d, Evidence, § 485.
13. Ibid., § 785.

representation of what it purports to portray. In order to insure success in court, the lane in which the car is traveling and the background should be clearly identifiable as the HOV lane. Consideration should be given to painting identifying marks on the road which can be seen in the photograph. The time and date must appear as well. Ideally, it would be stamped on the negative as the photograph is taken. Testimony of a witness is required to authenticate the photograph—the witness must "identify" by testifying as to persons, places or things shown. It is not usually necessary that the person who took the photograph be called as a witness to verify it—one having the required knowledge of the facts may verify or authenticate the photograph.[14] For the introduction of HOV photographs, the instrument taking the photograph would also have to be certified. (See ISSUE 2).

In a number of states where traffic offenses are considered to be minor criminal offenses or misdemeanors, statutes usually provide that a defendant need not appear at a misdemeanor trial. Nevertheless, the general rule is that although a defendant may waive his right to be present at the trial, he cannot claim the right to be absent since the prosecution has the prerogative of requiring his presence for purposes of identification. A number of states have statutes specifically compelling the attendance of defendants for purposes of identification. Although statutes may vary from state to state, all courts have ample resources for exerting jurisdiction over the defendant, compelling him to appear for trial in order to be identified.[15]

Expert Witness Testimony

The admissibility of HOV photographs and the types of or need for expert witness testimony will depend a great deal on the extent of the instrument certification requirements and judicial acceptance of the instrument (See ISSUE 2). The more stringent the requirements, the more rigorous will be the expert witness examination and qualifications. Judicial and scientific acceptance of the HOV instrumentation may result in statutes similar to the following one dealing with testimony as to speed calculating devices:

> "a witness otherwise qualified to testify shall be competent to give testimony against an accused violator of the motor vehicle laws of this state when such testimony is derived from the use of such an electronic, electrical, mechanical or other device used in the calculation of speed upon showing the speed calculating device which was used had been tested. However, the operator of any visual average speed computer device shall first be certified as a competent operator of such device by the department."[16]

Opinion evidence may be given by one who is competent to testify as an expert on the subject. He need not be at the top of his profession. Generally, courts allow a person whose profession deals with the subject at hand to be heard as an expert.[17] The trial courts have the discretion to decide whether an expert witness has sufficient knowledge to testify and qualify as an expert. The party offering the expert witness must show that the expert witness has the necessary learning, knowledge, skill of practical experience to enable him to give such testimony. Many courts also allow the

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14. 29 Am. Jur. 2d, Evidence § 788.

15. Dreyer, C.B. and Hawkins, T.E., op. cit., p. 32.
State of Minnesota v. Super, 161 NW 2d 832 (Supreme Court of Minnesota 1968).

16. Florida Statutes § 316.058 (3) (a).

17. 31 Am. Jur. 2d, Expert & Opinion Evidence, § 30.

opposing counsel to cross-examine as to the qualifications and competency of the witness. When the trial judge permits the expert to testify, the trial court rules, by inference, that the expert witness is qualified.[18]

On direct examination of an expert witness, the witness must give his own opinion regarding the subject at issue. An expert witness is generally not permitted to read from a treatise or give a treatise author's opinion as his own. The witness may testify that other or all authorities support his opinion and he may also refer to scientific books or publications as providing a basis for his opinion.[19] It is essential that an opportunity for thorough, cross-examination be given. On cross-examination, the witness may be examined about the whole subject matter dealt with on direct examination and he may also be examined on treatises he relied on to support his opinion. Some courts go so far as to allow the expert witness to be attacked on the basis of authorities which were not those used by him.[20]

Confidentiality and Destruction of Photographic Records

Every photograph taken to detect HOV lane violators will be developed in order to determine which drivers committed lane infractions. Problems of confidentiality will naturally arise.

Legislators have the power to enact statutes and ordinances regarding public records. If the definition of "public record" were to include HOV photographs, such photographs could be open for public inspection in the same manner as all other state, county, and municipal records.[21] However, an exception to this requirement may be recognized where police investigative files are at issue. Whereas records relating solely to office or personnel matters within a police agency or other matters unrelated to the "detection, apprehension and prosecution" of crimes may be open for public inspection, records which involve investigation of criminal or non-criminal matters may be precluded from public inspection.[22] Those photographs which do not show an HOV violation are not pertinent to investigative matters and should be destroyed upon development and a showing of no violation. Those photographs indicating an HOV violation would be classified investigative and should be retained as non-public records, until exhaustion of any legal appeal or statute of limitations. Use of photographs for other than HOV enforcement may constitute illegal surveillance.

Destruction of HOV photographs may also hinge upon whether they are considered an exception to the public record statutes or ordinances. If a public record, disposal of HOV photographs may require consent from the appropriate division of archives or records.[23] If the HOV photographs are removed from public inspection, then destruction can be freely accomplished.

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18. 31 Am. Jur. 2d, Expert & Opinion Evidence, §31 & 32.

19. Ibid., § 66.

20. Ibid., § 67.

21. Florida Statute § 119.01.

22. Opinion of Attorney General of Florida, 073-166, May 1973.

23. Florida Statute § 286.011.

State laws requiring all official meetings of any public (state, county, or municipality) boards, commissions, agencies, and authorities to be open to the public at all times may also require that all their records be open to the public. It is doubtful that such laws would encompass or affect HOV photographs and their confidentiality.

INSTRUMENTATION AND CERTIFICATION REQUIREMENTS

An HOV photographic instrumentation technique would undoubtedly need to undergo the process of securing judicial accpetance of the technique. Such was the case in the use of "radar" speed detection equipment. Credentials of a judicially unestablished scientific device must be proved by expert witness testimony. Until judicial notice is taken of the complete reliability and acceptance of the device, an expert witness must testify for each court case that the electronic and photographic principals involved in the operation of the device are scientifically sound and the evidence generated by the equipment is reliable and trustworthy. Given sufficient training, police officers and para-professionals could be trained as experts in the workings of the HOV equipment such that their testimony would sufficiently satisfy the expert witness requirement. After judicial acceptance, the need for repetitious expert verification will no longer be necessary.[24]

After this acceptance, the court procedure would still involve a validating witness, but his testimony would be simplified. After the prosecution presents the evidence, the officer may be called to testify as to the proper evidentiary procedures followed and that the photograph was not altered in any way. He may also be required to testify as to other details in the photograph.[25] After qualification of the validating witness, the legislature may provide that "upon the production of the certificate, signed and witnessed, showing that such device was tested within the time period specified and that such device was working properly, a presumption is established to that effect unless the contrary shall be established by competent evidence."[26] In other words, a certificate could be substituted for verbal testimony.

Once the scientific device is accepted, the defendant may challenge the evidence on grounds he was deprived of his right of cross-examination because the instrument was unmanned. Such objections were unsuccessfully made in radar cases, and the courts generally have held that cross-examination of the officer maintaining the device or the expert preserves the defendant's right of cross-examination.[27]

The extent to which radar verification officers were required to testify (as to the reliability of a scientifically unestablished device) is probably similar to the extent of testimony required in an HOV photographic instrumentation technique. The more widespread the system, the faster will judicial acceptance be accomplished, but predicting that time period of acceptance is not possible.

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24. Dreyer, C. B. and Hawkins, T. E., op. cit., p. 32.

25. Ibid., p. 33.

26. Florida Statutes § 316.058 (3) (b).

27. Dreyer, C. B., and Hawkins, T. E., op. cit., p. 32, Citing of City of Webster v. Quick, 319 SW 2d 543 (1959).

Radar

HOV photographic instrumentation would most likely face extensive questioning and require expert witness testimony, such as was required of radar. Early cases involving radar evidence required expert testimony as to the nature and function of a radar speed meter and the scientific principals upon which it is based. It is now generally agreed that the reliability of radar is a proper subject of judicial notice. There has also been legislative acceptance of the radar speed meter and statutory provisions permitting the use of radar in speed regulation enforcement have been passed to eliminate the necessity of presenting expert evidence as to radar's ability to measure speed. However, despite recognition of radar's general reliability, proof of the accuracy of the particular speed meter involved may still be required.[28]

Mobile ORBIS III Speed Enforcement Demonstration Project[29]

This project utilized instrumentation of an integrated speed computer and camera system for speed-detection and producing photographs of both the vehicle and driver. The deomonstration project occurred in Arlington, Texas, and it encountered the instrumentation certification process that HOV photographic instrumentation would probably similarly face. An ORBIS III officer was required to testify extensively as to the innermost workings of the ORBIS unit and its acceptability in the scientific realm. Testimony was required as follows: (1) that the machine was maintained under the officer's exclusive control during the specific period of time; (2) that the film was installed by the officer; (3) that he installed or set the various information items on the display panel; (4) and that he tested and rechecked the accuracy of the speed timer. In addition, speed checks were to be routinely made by the officer driving through the sensor zone at the speed indicated on his officially calibrated speedometer.[30] The ORBIS III system was recently discontinued, partially because of the court's requirement that an expert witness testify at each case concerning the unit's technical operation.

VISIBILITY OF OCCUPANTS

The Fourteenth Amendment to the United States Constitution prohibits any state legislation from denying to any class, race, or individual the equal protection of the laws. Unless the class is a "suspect" class (i.e., classification based on race or nationality) or the right at issue is a "fundamental" right (i.e., constitutionally protected right), courts require only that the legislation proposed or enacted by the State bears a reasonable or rational relation to a legitimate governmental interest. Presently, age is not considered a "suspect" classification and, therefore, the State need meet only the rational basis test for legislation that may affect on the basis of age.[31]

The basis for this issue is that the required number of occupants in a vehicle for traveling in the HOV lane will be related solely to their visibility. As a result, the possibility exists that small

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28. 47 American Law Reports (ALR) 3rd 822.

29. For further information on this project, please see pages 173 and 197.

30. Dreyer, C. B., and Hawkins, T. E., op. cit., p. 33.

31. Massachusetts Board of Retirement vs. Murgia, 427 U.S. 307 (U.S. Supreme Court) 1976.

children, persons lying down in the car, or persons situated in unvisible locations within the car (i.e., behind the side window frame or behind the front-seat head-rest) would not be visible to the photographic equipment or officer on surveillance. It would be necessary to write into the legislation a presumption clause that unless the required number of persons are visible, the vehicle is a violator. Statutory language to that effect might read:

> " . . . visibility of less than the required number of occupants in the subject vehicle operating within the HOV lane, as caught by the citing officer or approved photographic instrumentation, shall constitute in evidence a prima facie presumption that the driver of such vehicle is an HOV lane violator."

A statutory presumption provides that certain facts shall be prima facie evidence of other facts (see page 186). If there is a rational connection between the fact proved and the ultimate fact presumed, there is no denial of due process of law or equal protection provided also that the party affected is given a reasonable chance to present all the facts on the issue. This visibility presumption may be a rebuttable presumption such that the driver of the vehicle could present proof of the existence of the required number of occupants. For example, a driver cited for an HOV violation may present evidence (governed by the applicable rules of evidence) that the car had the required number of people, at the time of the alleged violation. The importance of this statutory language is that the burden of proof is initially upon the motorist, not the citing officer.

Because the presumption is rebuttable, it may be advisable to make visibility an element of the violation:

> " . . . visibility of less than the required number of occupants in the subject vehicle operating within the HOV lane, as caught by the citing officer or approved photographic instrumentation, shall constitute a violation."

This change and posted notice on the facility that visibility is required, eliminates the defense of small children or people lying down in the vehicle. A driver in violation would be on notice not to use that lane. Evidence of other people in the vehicle would be irrelevant and not admissable in court.

If the State can show the legitimate interest it has in preserving natural resources and improving the public convenience via HOV projects and that its legislation is a reasonable means for accomplishing this objective, challenges on the basis of age discrimination or visibility discrimination should be difficult to be upheld.

MAILING OF CITATIONS TO OWNER OF VEHICLE

The legal environment to mail HOV citations to the owner of a vehicle violating the HOV facility would exist if two legal concepts—decriminalization and presumption (see pages 187 and 188) are included in the jurisdiction's statutes and/or ordinances. Inclusion of these two legal concepts should preclude challenges made against citations mailed to the registered owner.

By establishing an HOV violation as a non-criminal infraction, "traffic infraction enforcement officers" (para-professionals) under appropriate statutory authority would provide a valuable resource

in the enforcement of HOV violations thus relieving police officers for other duties. Such a statute may provide as follows:

> "A sheriff's department or police department of a chartered municipality may employ, as a traffic infraction enforcement officer, any individual who successfully completes at least two hundred (200) hours of instruction in traffic enforcement procedures and court presentation through an approved departmental program. Any such traffic infraction enforcement officer who observes the commission of a traffic infraction could issue a traffic citation for such infraction when, based upon personal investigation, he has reasonable and probable grounds to believe that an offense has been committed in violation of noncriminal traffic infraction as defined by law. Such traffic enforcement officer could be employed in relationship to a selective traffic enforcement program at a fixed location or as part of an accident investigation team at the scene of the vehicle accident or in other types of traffic infraction enforcement under the direct immediate supervision of a fully qualified law enforcement officer."[32]

The presumption that the violating driver and the registered owner are one and the same person should meet the test of reasonableness for such a rational connection does exist. If a prima facie case is so established against the vehicle owner, the State's position will prevail if no proof is offered to the contrary. If the owner wants to avoid the effect of such a prima facie case, he must produce evidence against it. If the owner produces evidence that he was not the driver of the vehicle at the time of violation, this evidence for the defense equalizes the State's prima facie evidence.[33] Applicable rules of evidence and the attitude of the court, will govern in such a case. Possible evidence for the defense may include testimony of witnesses, affidavit from employer, or other documentary evidence indicating the owner was elsewhere. Proceedings will obviously vary from jurisdiction to jurisdiction.

Most states[34] have established prima facie evidence presumptions in municipal parking ordinances whereby the registered owner is presumed to be the violator. These prima facie presumptions have been found to be valid and constitutional. Where moving violations are treated as noncriminal infractions, they may be considered no different than parking violations. This is especially true where no points are assessed against a driver's record for the violation and the only penalty is a fine.

The effectiveness of mailing of citations to the registered owners of vehicles violating the HOV facility is dependent upon a successful prosecution of offenders. Experience has shown that the average driver receiving a simple citation will respond to it by paying the civil penalty or forfeiting bond in lieu of a hearing. If the driver totally ignores the citation mailed to him, his appearance in court can be ensured through the issuance of a summons against him.[35]

Should it develop that the owner and driver are not the same person, the owner can be petitioned (i.e., a written request of plea in which a specific court action is asked for) to properly identify the driver. Should the owner refuse to identify the driver, most states have ample authority to compel the owner to present such evidence. The owner is protected only by the Fifth Amendment right against self-incrimination and therefore may be forced to respond and reveal the true violator. Pro-

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32. Florida Statutes § 318.141.

33. 29 Am. Jur. 2d, Evidence §1165.

34. People v. Kane, 282 N W 248 (Michigan); City of Columbus v. Webster, 164 N E 2d 734 (Ohio); City of St. Louis v. Cook, 221 S W 2d 468 (Missouri); People v. Bigman, 100 Pa. 2d 370 (Pennsylvania).

35. Dreyer, C. B., and Hawkins, T. E., op. cit., p. 31.

vided the owner has no statutory protection (i.e., immunity), failure to provide the court with the required information could result in a judgment of contempt against the owner. Should the owner claim privilege (i.e., a basic civil right guaranteed by government) about withholding evidence of the driver, the laws of most states limit that privilege to the owner and his spouse. This privilege does not extend to the owner's child(ren), who, in many such cases, will be found to have been driving at the time of the violation.[36]

In cases in which the owner ignores the mailing of a citation or if he presents evidence at a hearing that he was not the driver of the vehicle at the time of the HOV violation, it could be a costly proposition then in order to pursue prosecution of the violation.

As of the present time, two states (Massachusetts and Texas) have successfully mailed citations to the registered owner of a vehicle for a moving violation. One state (Pennsylvania) allows the inference that the owner of a vehicle, merely because of his ownership, was operating the car, whereas another state (New York) disallows a quite similar inference.

Massachusetts

Massachusetts General Laws provide where a police officer observes a moving violation and is unable to give the original citation to the violator at the time of the offense, the citation shall be issued to the registered owner of the vehicle. Massachusetts law further provides that proof of the registered owner shall be prima facie evidence that such owner was the operator at the time of the violation.[37] This mailing procedure was used in the enforcement of the Southeast Expressway concurrent-flow lane project in Boston.[38]

Texas

The Mobile ORBIS III Speed Enforcement Demonstration Project in Arlington, Texas,[39] consisted of a mobile van having instrumentation that could photograph in a single frame the driver's face and the vehicle's front license plate as well as record speed, time and date on the photograph. Speeding violations were then issued to the registered owners of the vehicle. In the absence of the violator, Texas law authorizes mailing of such civil citations. The Attorney General of Texas gave an opinion that such a photograph was not an actionable invasion of right of privacy and, therefore, the photograph and driver registration information (from photograph of license plate) were considered sufficient grounds to issue the citation. Most owners responded to the citation (or notice of violation) by paying the fine on the basis of that citation. However, there were cases where an owner refused to pay the fine or otherwise respond to the citation. When this occurred, several methods were used to insure the defendant's appearance in court. If the processing officer (i.e., one who serves a summons) concluded that the driver and the owner were the same person, a summons was issued against him. If it could not be reasonably

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36. Ibid., p. 31 and 32.

37. Commonwealth of Massachusetts vs. Mini-Cost Car Rental, 242 N E 2d 411, 1968; Commonwealth of Massachusetts vs. Pauley, 331 N E 2d 901, 1975.
Massachusetts General Law c. 90C, s. 2.

38. For further information on the enforcement of this project, please see page 170.

39. For further information on this project, please see pages 173 and 194.

assumed that the owner was the driver, a "John Doe" warrant was issued for the person whose picture appeared in the photograph. Such a warrant was directed to the registered owner by the appropriate local official who decided on a direct comparison basis when serving the warrant, whether the person in whose name the vehicle was registered and the person in the picture were different, or one and the same. If the owner and driver were not the same person, the processing officer could petition (i.e., a written request or plea in which a specific court action is asked for) the owner to properly identify the driver and a summons could be issued to that person.[40]

Pennsylvania

A Pennsylvania statute provides that for a moving violation, the license plate on the vehicle would be prima facie evidence that the owner of the vehicle was operating it, but that the evidence could be rebutted by the owner. This statute withstood constitutional attack since the car owner was given reasonable opportunity to present his defense.[41]

New York

During the early 1950's, an enforcement project took pictures of the license plates of vehicles involved in traffic violations and then mailed the citations to the registered owners of the vehicles. In the absence of legislative action, New York courts would not infer that the owner of the car, merely because of this ownership, was operating the car.[42]

NON-WITNESSING OFFICER ISSUING THE CITATION

Analogous to citing an HOV violator by a non-witnessing officer, is the citing of a speed violator by a non-witnessing officer. Speed devices such as radar and air surveillance have been used extensively to allow non-witnessing officers to cite the violator. Acceptance of such a citing procedure varies from jurisdiction to jurisdiction. Where the appropriate statutes and/or ordinances have been passed or judge-made law has evolved, such citations issued by non-witnessing officers have been consistently upheld by the courts.

A common radar procedure is where the police officer operating the device radios ahead a description of the violating car to another officer stationed some distance farther on , and the car is intercepted by the second officer.[43] The validity of statutes permitting the use of radar speed meters to enforce the regulations has been consistently upheld.

A Florida Statute provides that "any police officer, upon receiving information relayed to him from a fellow officer stationed on the ground or in the air operating such a device that a driver of the vehicle has violated the speed laws of this state, may arrest the driver for violation of said laws where

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40. Dreyer, C. B., and Hawkins, T. E., op. cit., p. 31.

41. Commonwealth of Pennsylvania vs. Foulke, 22 Pa. D & C 135 (1933); 49 American Law Reports (ALR) 2d 456, 460.

42. People vs. Hildebrandt, 308 N.Y. 397, 126 N E 2d 377 (1955).

43. 47 American Law Reports 3d 822.

reasonable and proper identification of the vehicle and the speed of same has been communicated to the arresting officer."[44]

It would appear that such judicial holding or statutes are flexible enough to be modified such that they would apply likewise to violations other than of the speed laws.

ALLOCATION OF POWERS TO THE ENFORCEMENT AGENCY

The five previous legal issues identified appropriate changes in the legal environment to aid the enforcement of an HOV facility. The allocation of such powers to the enforcement agency carries with it the existing possibility that such powers may be abused. The possibility of abuse may be minimized by regulations within the agency as to proper enforcement of the HOV requirements, resulting in the removal of officers found to violate said regulations. Judicial policing by the courts, such as in suppression of illegally seized evidence, will further serve to minimize abuses of power.

Presumption

The use of the statutory presumption clauses can aid the enforcement agency in its HOV enforcement duties. The two presumptions are:

(1) the driver in violation of the HOV facility is the registered owner of the vehicle; and

(2) the number of persons visible in a vehicle indicates the number of persons in the vehicle.

These presumptions should not be open to abuse since the judicial process affords the defendant the right to rebut the presumptions.

Decriminalization

Decriminalization of HOV violations will aid the enforcement agency by minimizing the necessary due process requirements and expediting processing of infractions. Where speeding violations have been so decriminalized, abuse of this action has not been of consequence. Decriminalization of HOV violations should be accomplished through appropriate legislation, and appropriate agency regulations regarding their enforcement will have to be promulgated.

Para-Professionals

The institution of a Traffic Infraction Enforcement Officer Program would provide the enforcement agency with para-professionals specifically trained to handle enforcement of traffic problems such as HOV violators. A code of conduct and supervision by police officers would minimize abuse of such a program.

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44. Florida Statutes § 316.058 (2).

Mailing of Citations

With decriminalization of HOV violations and the prima facie case created for the prosecution, the enforcement agency should find legal acceptance for its mailing out of citations. Photographic enforcement of HOV regulations would allow mailing of citations to all violators photographed. Enforcement agency regulations should provide for no discretion in citing the violators and for appropriate punishment for misuse of this process.

Tandem Patrol

The use of a tandem patrol would allow the witnessing officer to alert the citing or arresting officer as to the violation of the HOV lane. Just as officer-teams using radar or other electronic speed equipment are subject to agency regulations, so should teams using the HOV equipment be regulated in order to minimize abuse of their power.

Statutes, ordinances and regulations governing the enforcement and enforcers of HOV violations must be accompanied by appropriate discipline of those officers who are responsible for carrying out the law.

MODEL LEGISLATION

Regardless of how technically sound the enforcement program might be, the legal environment must be compatible with the enforcement technique in order for the latter to operate effectively. The previous chapter reviewed the legal issues posed by a select number of innovative enforcement techniques. This chapter presents the model legislation that would be necessary to satisfy the legal requirements of HOV enforcement operations.

This model legislation was developed by modifying existing legislation and drafting new legislation. It is presented to the extent possible in modular form for flexibility. This modularity allows agencies, that are responsible for HOV operations, to select only the particular sections of the model legislation pertinent to their needs for inclusion into a specific HOV statute or ordinance. In this manner, the unwanted or undesirable sections of the model legislation will be omitted from the specific statute or ordinance allowing the latter to have a greater chance of passage by the legislative body.

There are seven major sections to the model legislation:

Section 1	—	Definitions
Section 2	—	Official Traffic Control Obedience
Section 3	—	Visibility of Occupants
Section 4	—	Information of Arresting or Citing Officer
Section 5	—	Service of Citation
Section 6	—	Registered Owner Presumed to be Operator
Section 7	—	Penalty

Table 31 identifies the sections of the model legislation that are applicable to each legal issue. The innovative enforcement techniques for each legal issue is also identified. It is not necessary to develop model legislation to address the photographic instrumentation technique. As summarized by legal issues one and two, it is presently legally permissable for photographic traffic enforcement to occur.

TABLE 31
MODEL LEGISLATION SECTION AND INNOVATIVE ENFORCEMENT TECHNIQUE APPLICABLE FOR EACH LEGAL ISSUE

Legal Issue	Model Legislation Section	Innovative Enforcement Technique
1. Admissibility of Photographic Evidence	Not Applicable	Photographic Instrumentation
2. Instrument Certification Requirements	Not Applicable	Photographic Instrumentation
3. Visibility of Occupants	Section 3	Photographic Instrumentation
4. Mailing of Citation to Owner of Vehicle	Sections 1.4, 1.5, 3, 5, 6 & 7	Mailing of Citation; Para-professional
5. Non-witnessing Officer Issuing the Citation	Section 4	Tandem Patrol

The model legislation for enforcement of high-occupancy vehicle facilities is presented on the following pages. It is unlikely that a particular agency would desire to incorporate each section of the model legislation into its specific HOV statute or ordinance. This model legislation is presented in modular form to allow for the agency to select the desired sections appropriate for their individual HOV enforcement needs. It is certainly advisable that each section be "edited" by the agency for conformity to its existing legal structure.

MODEL LEGISLATION FOR ENFORCEMENT OF HIGH OCCUPANCY VEHICLE FACILITIES

An Act relating to regulation of traffic; providing for use of preferential lanes by high occupancy vehicles.

SECTION 1: Definitions.

1.1 High Occupancy Vehicle. Public transportation vehicles, privately owned buses, or private motor vehicles carrying not less than (a specified number) of passengers (Washington Motor Vehicle Laws, RCW §47.52.025)

1.2 Preferential Lanes.

a. HOV Lane - That lane or set of lanes on a highway facility of any class, so designated by signing, pavement delineation or markings, and/or other means of positive guidance, that is reserved for the exclusive use of such authorized high occupancy vehicles during specified hours of specified days of the week, in order to provide preferential service over traditional, mixed vehicles on that remaining part of the same highway facility.

b. HOVway - An exclusive highway on its own right-of-way, alignment, or otherwise physically separated from the traditional mixed-flow traffic lanes of a highway facility, reserved for the sole use by such authorized high occupancy vehicles, emergency vehicles, or others as determined by the authorizing governmental agency.

c. Busway - An HOVway reserved for the sole use by authorized buses, emergency vehicles, or others as determined by the authorizing governmental agency.

1.3 Emergency Vehicle. Any vehicle of a governmental department or public service corporation when responding to an emergency, any vehicle of a police or fire department, and any ambulance.

1.4 Officer. Any law enforcement officer charged with and acting under his authority to arrest or cite persons suspected of, or known to be, violating statutes or ordinances regulating traffic or the operation or equipment of vehicles (Florida Statute § 318.13(5)). The term "officer" shall include "traffic infraction enforcement officers."

a. Any sheriff's department or police department of a chartered municipality may employ, as a traffic infraction enforcement officer, any individual who successfully completes at least 200 hours of instruction in traffic enforcement procedures and court presentation through an approved program. Any such traffic infraction enforcement officer who observes the commission of a traffic infraction may issue a traffic citation for such infraction when, based upon personal investigation, he has reasonable and probable grounds to believe that an offense has been committed in violation of noncriminal traffic infractions as defined by law.

b. Such traffic enforcement officer shall be employed in relationship to a selective traffic enforcement program at a fixed location or as part of an accident investigation team at the scene of a vehicle accident or in other types of traffic infraction enforcement under the direct and immediate supervision of a fully qualified law enforcement officer.

c. Nothing in this section shall be construed to permit the carrying of firearms or other weapons, nor shall traffic infraction enforcement officers have arrest authority other than the authority to issue a traffic citation as provided herein (Florida Statute §318.141).

1.5 Infraction. A noncriminal violation which is not punishable by incarceration and for which there is no right to a trial by jury or a right to court appointed counsel (Florida Statute §318.13(3)).

SECTION 2: Official Traffic Control Obedience. Drivers of vehicles shall obey the directions of every official traffic-control device which is erected to direct specified traffic to use a designated lane or designate those lanes to be used by traffic moving in a particular direction regardless of the center of the roadway (Traffic Laws Annotated, Section 11-309(c)).

SECTION 3: Visibility of Occupants. Less than the required number of occupants in a private motor vehicle operating within the designated preferential lane is a violation of the preferential lane regulation. Visibility of less than the required number of occupants, as caught by the citing officer or approved photographic instrumentation, shall constitute in evidence a prima facie presumption that the driver of the vehicle is in violation of the regulation.

SECTION 4: Information of Arresting or Citing Officer. A preferential lane violation is committed in the presence of an officer when facts and circumstances occuring within his observation, in connection with what may be considered as common knowledge including knowledge gained from approved photographic instrumentation, give him probable cause or reasonable grounds to suspect that such is the case, and for the purpose of determining the justification of a citation effected by one member of a multi-officer team from information conveyed to him by the others, the knowledge of one officer is the knowledge of all where reasonable and proper identification of the violation vehicle has been communicated to the citing officer.

SECTION 5: Service of Citation. Where a violation is observed by an officer or recorded by an approved photographic instrumentation and it is not possible to give the original of the citation to the violator at the time of such offense because the violator could not have been stopped or the failure is justified for some other reason, the citation shall be issued to the registered owner's last address (Massachusetts General Law c.90C, s.2).

SECTION 6: Registered Owner Presumed to be Operator. If any person operating a motor vehicle is observed in violation of these rules and regulations and the identity of the operator cannot be determined, proof of the registered owner of such vehicle shall be prima facie evidence that such owner was the operator thereof at the time of the violation.

SECTION 7: Penalty.

7.1 Any person cited for a violation of this section shall be deemed to be charged with a noncriminal infraction and shall be cited for such an infraction and cited to appear before an official.

7.2 Any person cited for an infraction under this section may:

a. Post a bond, which shall be equal in amount to the applicable civil penalty as established by statute; or

b. Sign and accept a citation indicating a promise to appear. The officer may indicate on the traffic citation the time and location of the scheduled hearing and shall indicate the applicable civil penalty.

7.3 Any person who willfully refuses to post a bond or accept and sign a summons shall be guilty of a misdemeanor of the second degree.

7.4 Any person charged with a noncriminal infraction under this section may:

a. Pay the civil penalty, either by mail or in person, within 10 days of the date of receiving the citation; or,

b. If he has posted bond, forfeit bond by not appearing at the designated time and location. If the person cited follows either of the above procedures, he shall be deemed to have admitted the infraction and to have waived his right to a hearing on the issue of commission of the infraction. Such admission shall not be used as evidence in any other proceedings.

7.5 Any person electing to appear before the designated official or who is required so to appear shall be deemed to have waived his right to the civil penalty provisions. The official, after a hearing, shall make a determination as to whether an infraction has been committed. If the commission of an infraction has been proven, the official may impose a civil penalty not to exceed $500.00 or require attendance at a driver improvement school, or both.

7.6 The commission of a charged infraction at a hearing under this chapter must be proved by a preponderance of the evidence.

7.7 The official having jurisdiction over the infraction shall certify to the department within 10 days after payment of the civil penalty or forfeiture of bond that the defendant has admitted to the infraction. If the charge results in a hearing, the official having jurisdiction shall certify to the department the final disposition within 10 days of the hearing (Florida Statute § 318.14).

CHAPTER EIGHT

SUMMARY

This report presents the results of the research study into the enforcement requirements of the high-occupancy vehicle facilities. The research focused on three major areas: 1) a review of the existing HOV enforcement practices and problems; 2) the identification of effective innovative HOV enforcement techniques; and 3) a review of the HOV legal environment and development of model legislation. Sixteen HOV projects were visited for research purposes by the research team. These projects encompassed virtually every type of preferential treatment strategy currently deployed in the United States on both arterial and freeway facilities. The major conclusions and recommendations by chapter are summarized below.

CHAPTER 1 — INTRODUCTION

A number of HOV projects have experienced sub-optimal levels of enforcement. This is due in part to a lack of engineering concern with enforcement, even though the enforcement issue has a considerable impact on the operational and safety characteristics of HOV projects, especially those where significant modifications to existing traffic patterns occur. As diversification in the design of HOV preferential treatment projects continues, the issue of enforcement of HOV facilities takes on greater importance, and the need for developing enforcement strategies which involves a systematic approach to violator apprehension becomes essential.

CHAPTER 2 — THE ENFORCEMENT PLANNING PROCESS

The major components of the enforcement planning process include:

1. setting objectives
2. defining potential enforcement problems
3. designing the enforcement program
4. developing an evaluation program
5. managing the enforcement program
6. developing a public education program

Traffic law enforcement personnel should be intimately involved in the planning effort to obtain their valuable insight into the nature of possible enforcement problems that may be encountered, and to gain their support and sensitivity to the constraints within which the transportation engineer has to work. In many cases, compromises may have to be made in terms of the final design concept and/or the desired enforcement program.

In selecting a final HOV design strategy for implementation, the enforceability of that concept should be taken into consideration. For each HOV design strategy, the project planning and design team should ask themselves, "How difficult will it be to enforce the restrictions associated with each of these strategies?" Possible modifications to the HOV design strategies should be explored to alleviate as many

potential enforcement problems as possible.

Once the HOV design concept has been selected from a number of candidate strategies, a comprehensive enforcement program should be developed. It is possible that several enforcement strategies, or more specifically several sets of procedures within a given strategy, may be applicable to the realistic enforcement objectives of any given HOV preferential treatment project. A careful review of the local legal environment and state statutory requirements should be made, particularly if innovative enforcement practices are under consideration. There are two very basic criteria which can be used to judge the performance of the various enforcement options. These are: 1) the projected violation rate, and 2) the projected cost of the enforcement program. The selection of the alternative that produces the best results per dollar invested can be made in a straight-forward manner. Unfortunately, detailed statistical information is sorely lacking to provide a highly scientific process for forecasting the violation rate.

In view of the lack of precise data on which to base the design of the final enforcement program, it is recommended that an evaluation plan be developed to assure a continuing flow of empirical data and feedback for program optimization. Specific areas relating to HOV lane operations and enforcement operations that should be quantified include:

- the relationship between the number of citations issued and the number of violations occurring
- the interrelationships between the violation rate, apprehension rate and the travel time savings of the HOV lane
- the changes in the violation rate due to changes in the quantitative, qualitative or substantive aspects of the enforcement program

It may be possible to reduce the enforcement level of effort without compromising HOV lane operations and enforcement objectives.

A detailed enforcement manual is highly recommended for effectively managing a complex HOV program. This manual should provide descriptions on the HOV project, system operations, enforcement procedures and reference information.

Public awareness is essential in any new enforcement program. If the public is made to understand the HOV operating strategy and its restrictions, the tendency to violate may be reduced. Furthermore, enforcement agencies uniformly concur that a public awareness program which notifies the public of enforcement activities increases the effectiveness of the enforcement effort. Inexpensive public education techniques available include news releases and conferences, public service advertising, transit advertising space, speakers' bureaus, pamphlets or handouts, and banners over the roadway. More expensive techniques include paid TV, radio and newspaper advertising, as well as roadside billboards. The primary message that should be transmitted with respect to HOV enforcement education should be a simple statement of: 1) what the law states and what is prohibited, 2) what will be done if a violation of that law occurs and 3) what the consequences are if a violator is apprehended or cited.

CHAPTER 3 — ENFORCEMENT SYSTEMS FOR PRIORITY TECHNIQUES FOR HIGH OCCUPANCY VEHICLES

The enforcement process is a system in which all component steps are undertaken in series. These steps are:

1. detection of the violator,
2. apprehension of the violator,
3. issuance of a citation to the violator, and
4. resolution of the citation.

There are many systems that could accomplish all or part of these steps but, in general, conventional techniques are the most predominant.

HOV Enforcement Programs

There are a number of interrelated elements which comprise the HOV enforcement program. These elements are:

1. enforcement strategies
2. enforcement procedures
3. objectives of the enforcement program
4. priority assigned to the HOV enforcement program
5. assignment of enforcement personnel
6. enforcement equipment
7. enforcement budget and funding
8. enforcement planning

Enforcement strategies as related to HOV projects can be organized into three broad categories: "routine," "special," or "selective." Routine enforcement are those enforcement activities which are randomly conducted in concert with the normal assortment of a uniformed police officer's duties. Special enforcement involves police activities planned and applied specifically to the HOV project on a continuing basis. Selective enforcement is a combination of both routine and special approaches, to the extent that special enforcement is applied periodically by officers in conjunction with a routine enforcement program. Routine enforcement can be an effective approach if the HOV project's geometric or operational features result in an acceptable (or tolerable) violation rate. If it does not, then special or selective enforcement would be required provided funds are available.

Enforcement procedures may vary among HOV projects because accepted traffic law enforcement practices consist of a myriad of procedures. HOV enforcement programs consist of procedures for 1) surveillance and detection, 2) apprehension and citation and 3) management approaches. Table 32 summarizes the enforcement procedures.

None of the HOV projects defined an enforcement objective in specific terms prior to the initiation of the project. This circumstance is not surprising when the uncertainty surrounding motorist reaction to an HOV project is considered, and little or no information is available to predict the effectiveness of planned enforcement strategies. The enforcement objective, whether stated formally or

TABLE 32

POSSIBLE ENFORCEMENT PROCEDURES

SURVEILLANCE & DETECTION	APPREHENSION & CITATION	MANAGEMENT APPROACHES
• Foot Patrol • Mobile Patrol • Stationary Patrol • Hidden Patrol	• Standard Pursuit • Stationary Apprehension • Wave-Off • Mail-Out of Warnings • Team Approach	• Interagency Approahc • Public Information Campaign • Enforcement Manual

informally, is generally described as: "to maintain the integrity of the HOV project." Once the HOV projects gain operating experience, some enforcement programs established a specific enforcement objective by defining a "tolerable violation rate." In most cases, the tolerable violation rate is defined as the violation rate currently being experienced on the project.

Enforcement programs for arterial and downtown HOV projects are not only concerned with HOV violations but with other restrictions as well. These include turning and parking prohibitions that may be necessary to implement the HOV project. For several projects, these types of restrictions pose a greater potential hazard than an occupancy restriction.

The level of relative priority assigned by the enforcement agency to the HOV enforcement program is usually indicated by the type of enforcement program selected for deployment. Special enforcement indicates relatively high priority due to the additional resources required to execute such strategies. The extra enforcement personnel associated with a special enforcement program are assigned in order to detect, apprehend and cite the violators of the HOV restrictions.

The number of personnel assigned to each HOV project is dependent on many factors, with the most significant ones being 1) project length, 2) project operation, 3) project restrictions, 4) enforcement strategy, and 5) availability of enforcement personnel and funds. The number of enforcement personnel assigned to cover an HOV project can be highly variable between very similar projects. The motor vehicle is the primary equipment item.

Generally, HOV enforcement programs are funded through the enforcement agency's existing budget. This is especially true for enforcement programs involving routine patrol and selective patrol strategies. Almost uniformly, enforcement agencies place the priority of HOV enforcement somewhere less than the priority of public safety activities and traffic law enforcement activities involving hazardous driving. In such a context, it may be impossible for the enforcement agency to allocate special funds for special or selective enforcement of an HOV project, and thus the HOV project must operate with routine enforcement.

HOV enforcement can be an expensive proposition. However, none of the enforcement agencies affected by an HOV project used this to justify special additional funding for its enforcement operations. However, HOV enforcement programs were considered in establishing some enforcement agencies' yearly

overall budgets. HOV enforcement should not necessarily be considered a drain on public funds. Each time a traffic citation is issued for an HOV violation, a fine is usually paid. The dollar amount of these fines are then allocated in some manner to the local and/or state government's treasury. It is possible for the dollar amount of fines collected for HOV citations to exceed the costs of enforcement for the HOV project.

Exclusive or preferential lanes for HOVs can be added to routes on the Federal-aid Primary, Urban, and Secondary Systems at the Federal participation level for those systems. The HOV lanes can be added to completed Interstate routes under certain conditions. Included for funding when HOV lanes are implemented on Federal-aid routes are the initial enforcement and personnel costs associated with implementing the HOV lane. Only Primary or Urban System funds can be used to provide 90 percent of these costs, regardless of the system.

One of the most significant factors in achieving a successful enforcement program is the early involvement in the planning process by representatives of the enforcement agencies affected. This is especially true for HOV projects that will require either special or selective enforcement. The advantages of the early involvement of the enforcement agency in the planning process of an HOV project centers on these areas: 1) provision of technical advice, 2) promotion of cooperative relationships, and 3) personnel planning and budgeting.

HOV Legal/Judicial Environment

HOV projects present two basic legal issues: first, whether or not the particular agency has the authority to conduct an HOV project; and second, what risks of legal liability are faced by the agency when traffic accidents occur causing damages and injury. It can be stated without trepidation that the legislature in any state has the power to authorize such projects. As a general matter, it cannot be denied that these projects fall within the typical police powers of the state. It is quite another matter, however, as to whether a particular agency has been delegated the authority by the legislature to conduct such a project. Under the present state of the law, if there is to be liability imposed upon an agency in respect to an HOV project, it would be under that branch of the law known to lawyers as the law of negligence. A second aspect of the liability question involves an analysis of the doctrine of sovereign immunity. Traditionally, in this country, governmental agencies were not held accountable for negligent acts on the theory that the government was immune to suit. That theory has broken down to some extent in almost every state, and has been completely abrogated in some states. There have been relatively few challenges of the authority of the HOV projects or their enforceability. There have been challenges of individual tickets but the project personnel who were interviewed could provide no specific information on these.

Generally, the HOV violation is cited either as a "failure to obey a traffic control device" if the project is based on general legislation or as a specific offense of the HOV designation if the legal statute/ordinance is more specific. The fine is dependent upon the fine schedule established within the jurisdiction responsible for the project, and ranges from $10 to $25 for the HOV projects investigated.

A good enforcement program can be undermined by the judicial branch of government if the judicial branch does not uphold the citations issued by the enforcement agency. An HOV project is

susceptible to misinterpretation by the judicial branch. Briefings for traffic court judges regarding the HOV project and its associated traffic regulations can be an important consideration influencing court attitudes. Judicial appreciation of the project's merits serves well toward developing the proper judicial support for the project. Specifically, the judges should be informed of 1) the objectives of the HOV project, 2) the traffic regulations applied to achieve the objectives, 3) the enforcement approach, 4) previous court rulings, if any, on similar projects, and 5) the legal basis for the restrictions and enforcement procedure.

HOV Enforcement Problems and Deficiencies

From the research conducted on the various HOV projects, transportation and enforcement officials have identified a number of problems and deficiencies associated with their HOV project enforcement programs. The problems are created by geometric, operational or institutional factors. The problems are:

1. The lack of a safe and easily accessible refuge area bordering the HOV lane which can be used to apprehend and cite HOV violators.

2. The absence of any vantage point by which enforcement can observe the HOV facility while keeping out of view may cause enforcement to be inefficient and too visible.

3. Some concurrent-flow HOV projects do not have the HOV lane physically separated by barriers, traffic posts or other implements from the general traffic lanes thereby providing the motorist with an infinite number of locations to violate the HOV regulation.

4. If an HOV facility does not have a paved surface, clear of obstructions, for passing, then apprehension maneuvers can be difficult since general traffic lanes, especially on freeways, are usually congested.

5. On HOV systems where carpools are permitted, the determination of the number of occupants in a vehicle is made difficult by 1) young children, 2) vans, mobile homes, etc., 3) mirrored glass, 4) hours of darkness, and 5) inclement weather.

6. Most HOV projects have a speed differential between the HOV lane and the general traffic lanes thereby presenting a significant safety concern for all traffic and especially enforcement.

7. For HOV projects where refuge areas are not adjacent to the HOV lane, the citing of HOV violators is less visible to the motorists.

8. Certain HOV restrictions require judgement decisions on the part of the enforcement personnel. The primary judgement situation faced by enforcement personnel focuses on curb bus lanes and the use of the bus lane by right-turning vehicles.

9. A good enforcement program for an HOV project requires proper coordination and cooperation between project management, enforcement and judicial interests. If the cooperation between any two participants deteriorates, for whatever reason, then the enforcement program will suffer.

10. Traffic law may limit the effectiveness of potential HOV enforcement programs. Because of geometric or operational problems associated with an HOV project, it may be extremely difficult for the "witnessing" officer to be the "apprehending" officer.

11. Manpower constraints face many enforcement agencies regardless of the traffic enforcement requirements imposed on the agency.

12. A low probability of being cited, especially when combined with a low fine, offers little incentive toward compliance with HOV restrictions.

HOV Enforcement Program Performance

The primary measure of effectiveness of an HOV enforcement program is the violation rate achieved. On most projects, and for the purposes of this report, the violation rate is defined as the percent of the total number of vehicles using the HOV lane which fail to meet eligibility criteria for the HOV lane. The violation rates for the HOV projects encompass a wide range of percentages—from a nearly zero percent violation rate to a violation rate of over 50 percent, the latter percent meaning that the majority of vehicles using the HOV lane are violators. Similar projects with similar geometry and operating strategies can have drastically different violation rates because of the type and level of enforcement employed.

The fact that an HOV project is experiencing a relatively high violation rate may not necessarily indicate failure of the HOV project objectives. The intent of employing a certain type of enforcement strategy is, in part, to achieve a violation rate that is agreed upon as tolerable to project management, enforcement personnel, motorists, or the general public. A high violation rate could very well be considered to be tolerable by the determinant group.

There are a number of factors that affect the violation rate. These include 1) HOV lane signing, 2) bus vs. carpool HOV lane restriction, 3) travel time benefits, 4) probability of apprehension, 5) accessibility to the HOV lane, 6) operating period, 7) occupancy restriction, 8) visibility, and 9) weather conditions.

When a motorist willfully violates the HOV lane, he presumably believes that he has a very good chance of escaping apprehension. In short, the motorist's perceived benefits outweigh the perceived risks associated with the violation. The overwhelming benefit that a motorist would receive is the travel time savings in the free-flowing HOV lane as opposed to the congested general lanes. The travel time savings, or perceived benefits, is but one side of the issue. If the probability of being apprehended for the HOV violation is 100 percent, then the violation rate would approach zero regardless of the magnitude of the travel time savings. The probability of being apprehended and cited for an HOV violation is dependent upon 1) the number of enforcement personnel assigned to HOV enforcement, 2) the time consumed by detection, apprehension and citation procedures, and 3) the number of HOV violators.

The overall effectiveness of any enforcement effort must be partially related to the time consumed by the detection, apprehension and citation procedures. These procedures are improved if the roadway and HOV operation contains features as 1) easily accessible refuge areas, 2) vantage points, 3) physical barrier between the HOV lane and general traffic lanes, and 4) passing zone or area.

Generally, one of the objectives of HOV projects is to improve traffic flow on the particular facility. However, enforcement of the HOV projects oftentimes disrupts traffic flow. The directly-related traffic flow problems are mainly associated with an apprehension procedure resulting in hazar-

dous weaving maneuvers performed by the enforcement vehicle alone or the enforcement/violator tandem. Once an HOV violator is escorted to a refuge area, the enforcement effort can be indirectly involved in disrupting traffic flow and contributing to traffic accidents through the phenomenon known as "rubbernecking," which is associated with the curiosity of motorists and the presence of enforcement of any kind.

CHAPTER 4 — ENFORCEMENT OF HOV PRIORITY TREATMENT PROJECTS ON FREEWAYS

There are certain recommendations on enforcement of HOV priority treatment projects which are common to all freeway applications. These recommendations are:

1. Enforcement requirements should be included in project planning in the earliest stages, and enforcement personnel should be active members of the planning team.

2. To the maximum extent possible, HOV priority projects should be designed, constructed and/or modified in strict conformance to AASHTO and MUTCD standards.

3. Officials of the traffic court system should be briefed, prior to the project start-up, regarding the project's operational goals, traffic restrictions, enforcement program and legal basis.

4. On projects having travel time savings as its operational goal, the HOV restrictions should be imposed only during those time periods when these savings can be achieved.

5. The entire project should be opened at one time (at least by direction).

6. Priority sections should be particularly well maintained.

7. Enforcement should be supported by extensive public education and publicity of the seriousness of the HOV restrictions.

8. Aggressive enforcement should begin immediately to instill a degree of respect of the HOV restrictions.

9. A readily accessible refuge area (full shoulders) should be provided for stationary observation and apprehension. If this is not possible, serious consideration should be given to extensive selective, special or instrumented enforcement tactics.

Separate Facilities

Separate freeway facilities for HOVs include separate roadways and exclusive ramps. These facilities are designated for exclusive use by specified HOVs and all other vehicles are expressly prohibited. The separation can be either permanent or partial. Separate facilities possess many of the operational characteristics of "tunnel" facilities, one of which is an irrevocable commitment to using the facility. This attribute makes separate facilities generally easy to enforce. If separation is not total, this enforcement benefit is diminished accordingly.

The separate roadway can lie within the median of the freeway or it can be entirely removed from the freeway. Completely separated roadways are really independent highways with no interaction with the general lanes, except at the terminal points. Partially separated lanes can have shared shoulders

which reduces right-of-way requirements. In this design, the restricted lanes are accessible from the general lanes and this increases the likelihood of violations.

Exclusive ramps are generally composed of two types. One type connects general-use lanes with HOV-specific facilities, such as bus terminals, in order to allow direct access to or from these restricted areas. The second type is the "typical" HOV priority facility which is intended to give preferential service to HOVs. There is a higher probability of violations on these ramps, since they also serve desirable origin-destination patterns of low occupant vehicles.

Separate HOV roadways characteristically have low violation rates, varying from 0 to 6 percent where separation is permanent and from 5 to 10 percent where violators can gain access/egress by crossing partial separations.

In regard to separated HOV facilities, the following specific recommendations are offered.

1. The facility should have full right and left shoulders. Separation should be accomplished by safety profile concrete barrier walls.

2. On partially separated facilities with common shoulders, the shoulders should be flush and easily accessible by disabled vehicles. On the other hand, they should be well delineated to discourage crossing the median shoulder.

3. On reversible facilities, access control must be positive. Use of lane control signals is suggested by the MUTCD and AASHTO but, in addition, gates or barricades should also be provided.

4. Access locations should be designed to meet the traffic demand but should also be upstream of bottleneck locations if possible.

Except for some project-specific reason, the enforcement strategy should involve mobile patrol of the general traffic lanes, while being conscious of the HOV facility. When the incidence of violations appears to be increasing, patrols should be stationed at strategic points on the shoulder of the HOV roadway. This surveillance should vary by timing and should use inconspicuous locations. Apprehension should generally be made on the HOV lane shoulder, unless a convenient exit can be safely reached.

Concurrent Lanes

Concurrent-flow HOV lane priority projects on freeways generally involve the designation of the median lane(s) for use by buses alone or by buses and carpools. Access to the restricted lane is most often continuous, that is, there is no physical separation or other barrier between the HOV lane and general lanes, and this feature makes concurrent lanes among the most difficult of HOV treatments to enforce. Concurrent HOV lanes can be created by either reserving an existing lane for HOV s or, more commonly, by constructing new lanes in the median. These two approaches have differing effects from an enforcement point of view. First, the addition of lanes often eliminates or reduces median shoulders or refuge areas which otherwise might be used as vantage points for police patrols and for issuance of citations. Secondly, "taking a lane" for HOVs most likely will increase the congestion in the general travel lanes and will thereby increase the perceived benefits (improved travel time), thus making it more "desirable" for a motorist to violate. The public acceptance of this type of HOV

treatment has been much better when new lanes are constructed for the HOVs.

The violation rates between concurrent flow lane projects can vary dramatically ranging from 10 percent to 60 percent.

In regard to concurrent flow HOV lane projects, the following specific recommendations are offered.

1. The facility should have median shoulders and refuge areas. These are needed both for public safety and to provide an area for officers to monitor HOV operations effectively.

2. On projects that operate in both directions during the same hour, median barrier cuts should be provided (if there is a median barrier) to enable motorcycle officers to enforce in both directions.

3. Signing and markings should conform rigidly to MUTCD standards, and special supplemental signs should be used as needed. Limits of the HOV priority section should be clearly defined. Special demarcation between the HOV lane and general traffic lanes can be provided by wider skip lines (8 inches) or a continuous row of mountable buttons.

The enforcement strategy should involve monitoring by motorcycle officers in the median. If not possible, mobile patrols in adjacent general lanes should then be used. Apprehension and detention should not generally be made in the median. Offenders should be pursued to the outside of the freeway and then off the facility in order to minimize disruption to traffic flow. If congestion is heavy in general lanes, extreme care should be exercised in escorting violators off the freeway. Where left hand exits exist downstream, violators should be escorted in the HOV lane to these exits.

Contraflow Lanes

The common application of contraflow HOV lanes is to assign the inside (median) lane in the opposing (off-peak) direction to a special class of vehicles. The contraflow lane is separated from the other travel lanes by insertable plastic posts. If sufficient capacity remains in the off-peak direction, an additional lane can be taken for use as a buffer lane. The vehicles qualified to use the contraflow lane are usually buses, although one project also allows taxis with passengers to use the contraflow lane. Typically, the contraflow lane section begins or ends upstream of a major bottleneck location such as a bridge, tunnel or toll facility. Buses (and other vehicles if permitted) enter the lane via a median cross-over or by a special ramp and proceed in the peak direction against the flow of off-peak direction general traffic, thereby bypassing congested traffic in the peak direction. The output terminal depends on the site and may be a cross-over merging with the general freeway or it may terminate at a bridge, tunnel or toll facility.

The violation rates on contraflow HOV lane projects approach zero percent.

In regard, to contraflow HOV lane projects, the following specific recommendations are offered.

1. Delineation of the HOV lane should include 1) removable safety posts and barricades, 2) changeable message signs at access points and 3) lane control signals (red "X" and green arrows) over the contraflow, buffer and adjacent general lanes.

2. Spacing of lane control devices should have at least one and preferably more devices in view of opposing traffic. Spacing of delineators should be close enough to discourage lane changes and a 40 feet (12.2 m) maximum spacing is recommended.

3. A buffer lane should be provided if possible.

4. Full right and left shoulders should exist for emergency stops in both the contraflow lane (median shoulder) and opposing general traffic (right shoulder).

5. If the output terminal is not inherently suitable for detaining violators (such as a toll plaza), a refuge area should be provided, preferably in the median.

6. Speed limits on both HOV and opposing general lanes should be lowered as necessary to reduce relative speeds.

7. Quick reaction incident detection and removal systems should be incorporated into the project. If possible, median cuts should be provided if there is no buffer lane so emergency vehicles can approach in the proper direction.

The most effective enforcement strategy is to have officers stationed at the access point to divert non-qualified vehicles from using the lane. Depending on the site-specific requirements of the project, the preferred strategy can be selective or continuous special enforcement. Routine freeway patrols should be extremely observant for violators and, more importantly, for incidents. Even accidents in the opposing general lanes can cause swerves into the contraflow lane by vehicles trying to avoid rear end collisions. Violators detected in the contraflow lane should be apprehended in the terminal area if possible.

Ramp & Metering Bypass

Ramp metering has been used for nearly two decades to improve general operations on freeways by limiting access onto the mainline of the freeway. As an incentive to HOVs, bypass lanes have been constructed which allow these vehicles "free" access to the freeway without the delays encountered by low occupancy vehicles at the ramp signal. The ramp metering bypass (RMB) technique can be used at isolated ramps, or can be incorporated into a series of ramps which collectively form a RMB HOV priority system. RMB lanes are generally constructed by widening existing ramps, or redesignating one lane of existing multi-lane ramps. RMB lanes can be the right or left lane depending on the geometric configuration of the ramp. RMB lanes can also be physically separated from the general lanes. This eliminates the interaction between HOVs and general traffic, thereby enhancing safety and enforcement.

The violation rates between RMB projects can vary dramatically ranging from 0-5 percent to 40 percent.

In regard to RMB projects, the following specific recommendations are offered.

1. Provide a physical separation between the RMB lane and the general ramp lane, if space and funding resources permit. If there is no physical separation, then there should be a solid white line demarcation between the lanes, supported by raised pavement buttons for additional emphasis.

2. A vantage point should be provided for a stationary officer to monitor the RMB lane out of view of the motorists. Adequate shoulders should be provided for apprehending and

ticketing violators.

3. The selection of right or left lanes as the HOV lane is important particularly on non-separated RMB ramps. Consideration should be given to access to the ramp, position of signals, vis. a vis. the stopped queue and how the two lanes will merge.

Because of the isolated nature of this priority treatment, continuous enforcement is impractical, particularly if a large number of ramps is involved. Bus-only RMB ramps are less prone to violations, but still require periodic attention. A selective enforcement system should be established whereby each ramp is targeted on a periodic, but random pattern. The enforcement assignment should be dependent on violation levels, which requires some type of data collection scheme.

Patrols, preferably motorcycle mounted, should station themselves where they can observe the HOV lane and the ramp signal and observe for violators. Preferably, the position is hidden from view. Once a violator is detected, he should be pursued or (if possible) waved over to the shoulder. Tickets should be issued in view of the ramp traffic for maximum effect since the disruption to ramp traffic is not as detrimental as it is on the mainline.

Exclusive Toll Plaza Lanes

A toll plaza is inherently a bottleneck on a freeway. In such instances, the capacity of the toll plaza is generally equal to or less than the upstream demand, resulting in extensive queueing in peak periods. Exclusive lanes for HOVs enable these vehicles to bypass the queue and gain access to the toll facility with less delay. This HOV priority treatment is relatively simple to implement if lanes and/or toll booths are redesignated from general traffic use to exclusive use by HOVs. Since toll plaza configurations vary greatly, there is no "typical" manner of implementing restricted lanes or booths for HOVs. Exclusive toll plaza lanes serve several purposes. They allow HOVs to 1) bypass queues on the approach, 2) move through the toll station with minimal delay, and 3) gain preferential access to the toll facility itself.

Exclusive toll plaza lanes for HOVs can operate efficiently and with relatively few violations. Selective enforcement when used periodically, can maintain a sustained violation rate which is lower than 10 percent.

In regard to exclusive toll plaza lanes, the following specific recommendations are offered.

1. Provide special areas, such as a refuge area or shoulder, adjacent to the HOV lanes in order for officers to monitor the HOV lane and conduct the enforcement operations.

2. Provide a physical separation, such as a barrier wall or raised curb, between the HOV lanes and general lanes so long as such a barrier does not pose safety hazards itself.

3. Where the facility is not metered, the capability of informing toll attendants to halt traffic should be included. This would "clear" the downstream roadway allowing police vehicles to pursue violators and, more importantly, allow emergency vehicles to travel unimpeded.

Mobile patrols should provide routine enforcement by monitoring the HOV lane operations from stationary positions, preferably adjacent to the lanes. The toll booths are an excellent location for

detection, but apprehension is disruptive. When warranted by increasing violation rates, selective enforcement teams should be called in to set up shunt lanes (if refuge areas do not exist) in which to store violators while being ticketed.

CHAPTER 5 — ENFORCEMENT OF HOV PRIORITY TREATMENT PROJECTS ON ARTERIALS

The nine recommendations for enforcement of HOV priority treatment projects, which are presented in Chapter 4 (see page 213) as being common to all freeway applications, are also common to all arterial street and highway applications.

Separate Facility

Separate facilities on an arterial street system are commonly referred to as "transitways" because the only type of vehicle that is generally permitted to travel on such a facility is the transit coach. There are two types of transitways, each serving a different objective. A transitway may serve as a major transit collection/distribution route providing benefits of transit accessibility and separation of different classes of vehicles. Also, a transitway may serve the line-haul portion of transit service providing the more traditional HOV benefits of travel time savings and increased total person through-put.

Transitways tend to be easily enforced and violations of the restrictions are virtually non-existent.

In regard to separate facility HOV lane projects, the following specific recommendations are offered.

1. Appropriate pedestrian controls should be instituted if pedestrian crossing is considered to be a safety problem. These controls include pedestrian cross-walks, pedestrian signals and strict enforcement of "jay-walking."

2. Procedures regarding bus operations on the transit-way should include: 1) reduced bus speeds, and 2) increased driver awareness and courtesy.

3. Cross streets across the transit-way should be eliminated whenever possible. When the elimination of cross streets is impossible, the turning movements between the transitway and the cross streets should be restricted.

4. It is important that terminal areas and any other access areas be well signed and marked and the traffic appropriately channeled.

The use of routine enforcement in either mobile or pedestrian modes should be satisfactory for HOV enforcement purposes.

Concurrent Lane

Concurrent flow priority applications on arterial highways involve reservation of either the curbside lane or the median lane for high-occupancy vehicles. These applications have differing operational objectives and somewhat differing enforcement requirements. Curbside lanes have historically been installed to provide better transit circulation in the CBD and/or to improve downtown traffic flow

through the segregation of buses and autos. A second objective may be to provide a travel time improvement (not advantage) for buses. Taxi-cabs, other vehicles loading and unloading passengers, right-turning vehicles, motorcycles and bicycles may also be permitted to travel in the curb HOV lane. Enforcement requirements on the curbside concurrent lanes address illegal stopping, parking or ineligible vehicular travel in this lane. Median lanes are generally intended to provide high-occupancy vehicles with travel time advantages by bypassing traffic congestion in the general traffic lanes. Enforcement requirements address the illegal travel in the lane as well as possible illegal turning movements across the median HOV lane.

Concurrent lane projects can be operated effectively with reasonably few violations, however this may require a special enforcement program. Without special enforcement, the number of violations may interfere with the operations of the HOV lane.

In regard to concurrent flow HOV lane projects, the following specific recommendations are offered.

1. Enforcement of HOV lanes may have an additional concern with parking and turning restrictions. These restrictions may require more enforcement attention than violations of the HOV lane itself.

2. For a median lane HOV treatment, use of left-turning bays (closed-off due to left turn restriction) have proven to be an effective area for enforcement vantage points and detention areas, when coupled with a special enforcement program.

3. Signing and markings should conform rigidly to standards, but special supplemental signs should be used as needed. Limits of the HOV priority section should be clearly defined.

4. For a median lane HOV treatment, cones or safety posts should not be employed to separate the HOV lane and general travel lanes. These implements can pose safety problems and do not favorably affect the violation rate.

5. For a curbside lane HOV treatment, locations should be available or provided where officers can apprehend and issue citations to violators without encroaching onto the main roadway. The use of cross streets may be an appropriate detention area.

6. For a curbside lane HOV treatment, the signing permitting right turns should specifically state the point at which a right-turning vehicle may enter the priority lane.

Median lane HOV treatments should be enforced by selective or special enforcement efforts. On curbside HOV lane treatments, routine patrols (mobile or foot) could be justified as capable of producing a tolerable violation environment. However, it is recommended that selective enforcement be periodically deployed to further enhance the credibility of 1) the HOV project, 2) the enforcement agency, and 3) traffic laws in general.

Contraflow Lanes

A contraflow HOV lane is commonly a lane in the off peak direction reserved for HOV vehicles traveling in the peak direction. It can incorporate the median lane or the curb lane of a highway facility. A contraflow HOV lane operating in the median lane is commonly associated with express bus service

operating in a through mode or on a line-haul trip. The major objective of the contraflow median HOV lane is to provide travel-time advantages to the HOV vehicles by bypassing traffic congestion in the general traffic lanes and traffic queues at signalized intersections. A contraflow HOV lane operating in the curb lane occurs on a facility which otherwise usually serves one-way traffic. This type of operation is commonly associated with local bus service making periodic stops for passenger loading and unloading. The major objectives of the contraflow curb HOV lane are to 1) separate the different classes of vehicles—bus and auto—in order to improve traffic flow on the facility and traffic circulation in the CBD, and 2) provide a travel-time advantage for the HOV vehicles (i.e., local buses).

Enforcement of both types of contraflow lane treatments are concerned with 1) violators of the HOV restrictions and 2) violators of the supplemental traffic restrictions necessary to operate the contraflow lane. The violators of the supplemental traffic restrictions are frequently of much greater concern to enforcement officials. Supplemental traffic restrictions may involve turning movements across the HOV lane, and parking or stopping in the HOV lane.

On a bus-only contraflow lane operation, the main concern for enforcement officials is generally not associated with violations of the bus-only restriction, but with possible violations of any associated turning or parking restrictions. Illegal turns are hazardous movements and can adversely impact safety.

Violations of the bus-only restriction are uncommon because 1) bus volumes in the contraflow lane can be high and this provides a self-enforcing feature, 2) a non-bus vehicle traveling in the contraflow lane is very conspicuous to police officers, and/or 3) the general lane traffic is moving in the opposite direction of the contraflow lane. With a bus/carpool contraflow lane, violations may be more prevalent because a violating vehicle is no longer as conspicuous as in the case with a bus-only restriction.

In regard to contraflow HOV lane projects, the following specific recommendations are offered.

1. In addition to HOV lane violations, enforcement also needs to focus on turning and parking restrictions. These restrictions may pose greater responsibilities for enforcement.

2. Geometric and/or traffic control techniques intended to eliminate or physically impede access/egress at intermediate intersections greatly enhances enforcement on contraflow facilities, and should be deployed where possible.

3. Overhead lane-use signals and signs should be used, especially where extensive visual clutter exists lessening the effectiveness of roadside signing.

4. The use of temporary traffic control devices, such as cones, gates, and signs on stanchions, has proven to be effective in eliminating illegal turns across the contraflow lanes on projects with physical medians. The elimination of illegal crossing turns on projects without physical medians will require site specific enforcement.

5. If possible, curbside contraflow lanes should be wide enough for a bus to safely pass a disabled bus. Wide lanes enhance enforcement by providing 1) an enforcement vantage point, 2) a passing lane for violator apprehension, and 3) a detention/citation area.

6. If possible, median contraflow lanes should have a median from which enforcement officers can monitor the project's operation. Without this median, enforcement will be increasingly difficult by requiring police to cross the general traffic lanes.

Routine line patrols should be adequate for enforcing many contraflow HOV projects. However, extensive turning restrictions when coupled with very little geometric and/or physical control of such restrictions can easily produce a significant amount of illegal and hazardous turning maneuvers. Such hazardous maneuvers could threaten the project's continuation and seriously compromise the safety of the motoring public. Therefore, it is recommended that selective and special enforcement strategies be considered in such situations. Specific selective or special enforcement may include stationary or mobile patrols.

Signal Preemption

A signal preemption system provides buses with a capability to control the traffic signals in order to obtain preferential treatment at signalized intersections. Signal preemption produces travel time savings to buses through the provision of increased green time when the applicable vehicle is approaching the signal. Signal preemption generally has the capability to 1) extend the main street green phase and/or, 2) accelerate the side street phase in order to advance a main street green signal. In short, signal preemption provides the bus with a high probability of receiving a green signal phase upon its arrival at each equipped traffic signal. Travel time savings to the bus can be further increased by the provision of a reserved lane for the bus, thereby allowing the bus to bypass any traffic queues and congestion, especially at the traffic signals.

The only possible violations requiring enforcement would be 1) unauthorized persons having and utilizing the signal preemption transmitter and 2) motorists unknowingly running the red light because of a change in phasing due to the signal preemption. These violations have not been reported on signal preemption projects.

Because there are no direct HOV enforcement requirements associated with the signal preemption priority treatment, there are no specific enforcement recommendations.

CHAPTER 6 — INNOVATIVE ENFORCEMENT TECHNIQUES

The readily-available innovative techniques that could benefit HOV enforcement include:

1. Use of photographic systems and instrumentation in detecting HOV violations and identifying the violators.

2. Use of law enforcement para-professionals in detecting HOV violations and identifying the violators.

3. Mailing of traffic citations and warning letters to the registered owner (identified through the license plate) of a vehicle violating the HOV facility.

4. Remote apprehension of the HOV violator on an exit ramp or other downstream location by an enforcement officer working in tandem with another officer detecting the HOV violation.

5. Mass screening of license tags to identify habitual violators.

Two separate research projects sponsored by the United States Department of Transportation have studied photographic instrumentation for enforcement purposes. These projects are 1) the Mobile ORBIS III Speed Enforcement Demonstration Project in Arlington, Texas, and 2) a Photographic System for Obtaining Auto Occupancy Counts. The Federal Highway Administration is presently extending this latter research in part to produce a photographic system specifically for the various needs associated with enforcement of HOV facilities. This photographic system consists of a camera, a stroboscopic light source and a vehicle-actuated triggering mechanism. Guidelines for applying photography to HOV enforcement are presented in Chapter 6.

The use of para-professionals has the benefit of removing the enforcement responsibility from a valuable resource in short supply—the law enforcement officer. The use of such personnel or civilian observers for non-arresting activities, such as data base development, could enhance the efficiency of the enforcement process.

The legal environment required to mail HOV citations to the owner of a vehicle violating the HOV facility would exist if two legal concepts—decriminalization and presumption—are included in the jurisdiction's statutes and/or ordinances. Inclusion of these two legal concepts should preclude challenges made against citations mailed to the registered owner. As of the present time, two states (Massachusetts and Texas) have successfully mailed citations to the registered owner of a vehicle for a moving violation. Also, two HOV projects have utilized to some degree this enforcement technique of mailing citations or warning letters. The projects are 1) the San Francisco-Oakland Bay Bridge priority lane project, and 2) the Southeast Expressway (Boston) concurrent-flow priority lane project. The San Francisco-based project mailed a warning letter, whereas the Boston-based project mailed a traffic citation.

An exit-ramp apprehension campaign could be based on one officer, who is stationed at a randomly selected off-ramp, receiving identification data (model, color, and license number of vehicle) of violators of the HOV lane restrictions from another officer patrolling the HOV facility. If an identified violator of the HOV lane passes the officer stationed on the exit ramp, apprehension could occur. The selection of the off-ramp, rather than being random, could be based on some type of violation pattern analysis. This analysis would predict the most probable exit ramp and time range for apprehension of habitual violators of the HOV lane restrictions.

A mass screening technique for license tags uses a small portable computer which stores information on vehicles which have been involved in certain types of unlawful activity. The data base is utilized by entering the license tag number of each vehicle encountered at an apprehension point. The system responds by indicating whether or not the driver should be detained. This concept could be adapted to HOV enforcement by defining the data base to include only those vehicles identified as repeated (but unapprehended) violators of HOV regulations.

CHAPTER 7 — LEGAL ISSUES

For many of the HOV projects which were surveyed, changes in law are necessary prior to the incorporation into the enforcement process of any innovative technique presented in Chapter 6. Certainly, a better understanding of the capabilities of traffic enforcement to execute such techniques within the existing legal environment is highly desirable. This research has identified six key legal issues

associated with the innovative enforcement techniques. Model legislation for enforcement of high-occupancy vehicle facilities is presented in Chapter 7.

Admissibility of Photographic Evidence

Courts have recognized that photographs may be relevant to the issues and may be introduced as evidence to establish identities. Foremost among the legal concerns of this issue are 1) invasion of privacy, 2) right to equal protection, 3) freedom of association, 4) photographs as evidence, 5) expert witness testimony, and 6) confidentiality and destruction of photographic records. It is highly unlikely that photographic evidence would be denied by the courts because invasion of privacy, right to equal protection or freedom of association. Photographs, when offered as evidence of the person(s) photographed, must be authenticated and supported by the testimony of a qualified witness. The types of or need for expert witness testimony will depend a great deal on the extent of the instrument certification requirements and judicial acceptance of the instrument. Use of photographs for other than HOV enforcement may constitute illegal surveillance. Destruction of HOV photographs may also hinge upon whether they are considered an exception to the public record statutes or ordinances.

Instrumentation and Certification Requirements

An HOV photographic instrumentation technique would undoubtedly need to undergo the process of securing judicial acceptance of the technique. Credentials of a judicially unestablished scientific device must be proved by expert witness testimony. Until judicial notice is taken of the complete reliability and acceptance of the device, an expert witness must testify for each court case that the electronic and photographic principals involved in the operation of the device are scientifically sound and the evidence generated by the equipment is reliable and trustworthy. Given sufficient training, police officers and para-professionals could be trained as experts in the workings of the HOV equipment such that their testimony would sufficiently satisfy the expert witness requirement. After judicial acceptance, the need for repetitious expert verification will no longer be necessary.

Visibility of Occupants

The basis for this issue is that the required number of occupants in a vehicle for traveling in the HOV lane will be related solely to their visibility. As a result, the possibility exists that small children, persons lying down in the car, or persons situated in unvisible locations within the car (i.e., behind the side window frame or behind the front-seat head-rest) would not be visible to the photographic equipment or officer on surveillance. It would be necessary to write into the legislation a presumption clause that unless the required number of persons are visible, the vehicle is a violator. This visibility presumption may be a rebuttable presumption such that the driver of the vehicle could present proof of the existence of the required number of occupants. For example, a driver cited for an HOV violation may present evidence (governed by the applicable rules of evidence) that the car had the required number of people, at the time of the alleged violation. The importance of this statutory language is that the burden of proof is initially upon the motorist, not the citing officer.

Mailing of Citations to Owner of Vehicle

The legal environment to mail HOV citations to the owner of a vehicle violating the HOV facility would exist if two legal concepts—decriminalization and presumption—are included in the jurisdiction's statutes and/or ordinances. Inclusion of these two legal concepts should preclude challenges made against citations mailed to the registered owner. Most states have established prima facie evidence presumptions in municipal parking ordinances whereby the registered owner is presumed to be the violator. These prima facie presumptions have been found to be valid and constitutional. Where moving violations are treated as noncriminal infractions, they may be considered no different than parking violations. This is especially true where no points are assessed against a driver's record for the violation and the only penalty is a fine.

Non-Witnessing Officer Issuing the Citation

Analogous to citing an HOV violator by a non-witnessing officer, is the citing of a speed violator by a non-witnessing officer. Speed devices such as radar and air surveillance have been used extensively to allow non-witnessing officers to cite the violator. Acceptance of such a citing procedure varies from jurisdiction to jurisdiction. Where the appropriate statutes and/or ordinances have been passed or judge-made law has evolved, such citations issued by non-witnessing officers have been consistently upheld by the courts.

Allocation of Powers to the Enforcement Agency

The five previous legal issues identified appropriate changes in the legal environment to aid the enforcement of an HOV facility. The allocation of such powers to the enforcement agency carries with it the existing possibility that such powers may be abused. The possibility of abuse may be minimized by regulations within the agency as to proper enforcement of the HOV requirements, resulting in the removal of officers found to violate said regulations. Judicial policing by the courts, such as in suppression of illegally seized evidence, will further serve to minimize abuses of power.

RESEARCH AND DEVELOPMENT NEEDS

Throughout the data collection phase of this research, very little quantitative data, as to citations issued and enforcement effort (manpower and dollars) expended, could be obtained for the purposes of conducting detailed quantitative analyses and rigorous statistical tests. These types of exercises would be most useful for evaluating the enforcement program's effectiveness and efficiencies. Specific areas relating to the enforcement research that would be desirable to quantify would include:

1. the relationship between the number of citations issued and the number of violations occurring
2. the interrelationships between the violation rate, apprehension rate and the travel time savings of the HOV lane
3. the changes in the violation rate due to changes in the quantitative, qualitative or substantive aspects of the enforcement program

Without the specific data to establish these relationships, it is difficult, if not impossible, to plan an enforcement program that will achieve a pre-determined objective. Even the trial-and-error technique will have limited success unless better performance measurement systems are applied to evaluate the enforcement program's effectiveness.

Enforcement can better respond to the proliferation of HOV projects through a quantitative assessment of HOV enforcement operations, the development of innovative enforcement tactics and technologies and the establishment of a complementary legal climate. In short, proper planning, cooperation between involved participants, the allocation of adequate resources, the use of rationally applied technology, and the articulation of contemporary enforcement methodology and policy can lead to the solution of a problem which thus far has been largely neglected.

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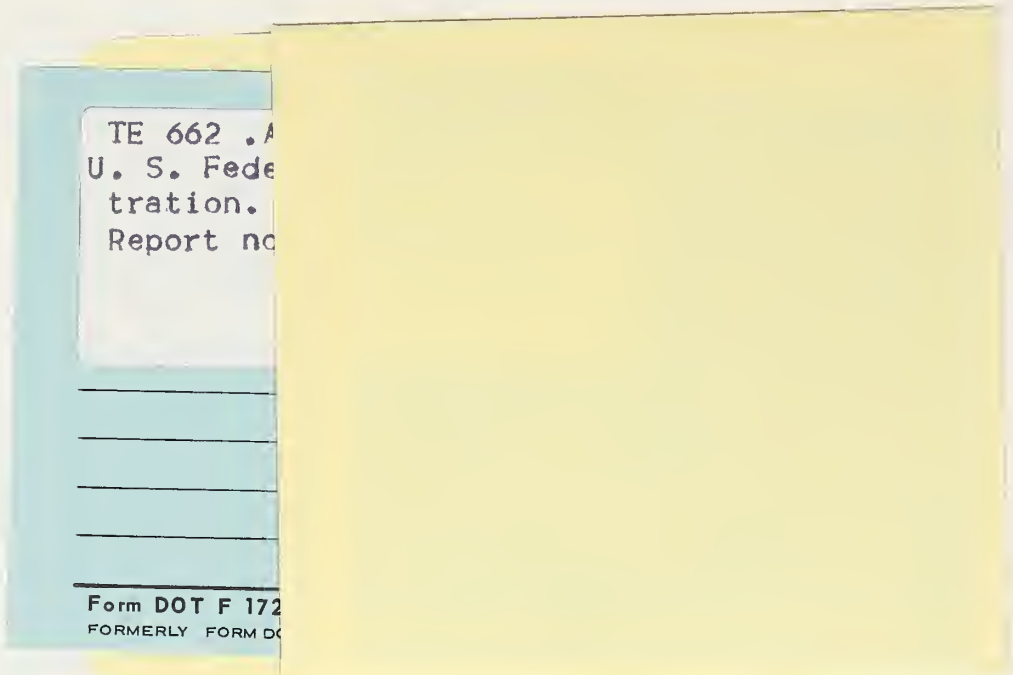

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