NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP Report 413

Development of an *HOV Systems Manual*

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This report documents gaps and weaknesses in the current practices for developing or expanding HOV (High-Occupancy Vehicle) systems. It describes the development of a companion publication, *NCHRP Report 414*, "HOV Systems Manual," and presents an implementation plan for transferring the completed HOV Systems Manual into practice. The contents of this Manual are, therefore, of immediate interest to both highway and transit professionals in planning, designing, implementing, operating, marketing, and enforcing HOV systems. The Manual is also useful to policy makers and to others charged with achieving air-quality and congestion-management goals.

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Report 413

Development of an *HOV Systems Manual*

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Planning and Administration
Energy and Environment
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Highway and Facility Design
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Public Transit

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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NOTICE

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration, U.S. Department of Transportation.

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FOREWORD

By Staff
Transportation Research Board

This report documents gaps and weaknesses in the current practices for developing or expanding HOV (High-Occupancy Vehicle) systems. It describes the development of a companion publication, *NCHRP Report 414*, "HOV Systems Manual," and presents an implementation plan for transferring the completed HOV Systems Manual into practice. The contents of this Manual are, therefore, of immediate interest to both highway and transit professionals in planning, designing, implementing, operating, marketing, and enforcing HOV systems. The Manual is also useful to policy makers and to others charged with achieving air-quality and congestion-management goals.

The Texas Transportation Institute (TTI) at Texas A&M University in College Station, Texas, was awarded NCHRP Project 3-53, "Development of a HOV Systems Manual," to evaluate existing specifications and procedures for various aspects of HOV systems, to identify alternatives and discuss their applicability, and to prepare a manual that would promote consistency and effectiveness in future applications and emphasize coordinated development of all elements of the HOV system. TTI was assisted in this effort by Parsons Brinckerhoff Quade and Douglas, Inc. (PB) in Orange, California, and Pacific Rim Resources (PRR) in Seattle, Washington.

The report contains both a state-of-the-art literature review of current HOV practices and guidelines and the results of an extensive survey of HOV practitioners. The gaps and weaknesses in current practice and knowledge were used to identify unresolved issues associated with HOV systems. The literature review, the survey, and the gaps and weaknesses are presented in 10 general categories: HOV Facility Policy Considerations; Planning; Design; Marketing; Operations; Enforcement; Implementation; Support Facilities, Services, Policies and Programs; Environmental and Air Quality Impacts; and HOV Facility Evaluations and Research Needs.

The report describes the development of the "HOV Systems Manual" (*NCHRP Report 414)* and offers an extensive implementation plan for ensuring that the Manual is quickly made available to practitioners and is incorporated into everyday use and practice. It also suggests that, as the gaps and weaknesses are filled by future research, those research results be presented in the same format as the *NCHRP Report 414* and be printed on three-holed paper for easy insertion into that Manual. This report further recommends that the Manual be completely reviewed every 5 years to determine major update needs and that a group well suited for implementing this review process and for presenting future research needs to the NCHRP is the TRB Division A Committee A3A06, High-Occupancy Vehicle Systems.

CONTENTS

AUTHOR ACKNOWLEDGMENTS

The research reported herein was performed under NCHRP Project 3-53 by the Texas Transportation Institute, a part of the Texas A&M University System; Parsons Brinckerhoff Quade and Douglas; and Pacific Rim Resources. The Texas A&M Research Foundation is the contractor for this study.

Dr. Katherine F. Turnbull, Texas Transportation Institute (TTI), and Dr. Donald G. Capelle, Parsons Brinckheroff Quade and Douglas, are the Principal Investigators. The major product from this research study is the *HOV Systems Manual*, which is provided as a separate document. The other authors who contributed to the HOV Manual are Mr. William Eisele, and Dr. Keith Knapp, TTI; Mr. Chuck Fuhs, Mr. Brian Pearson, and Mr. Kevin Haboian, Parsons Brinckerhoff; and Ms. Heidi Stamm, Pacific Rim Resources. The authors would also like to thank Ms. Pam Rowe, Ms. Bonnie Duke, Mr. Pat Beck, Mr. Stephen Farnsworth, and Ms. Laura Higgins for their assistance in typing the final report and *HOV Systems Manual*, preparing many of the graphics, and proofreading. The assistance of these individuals is recognized and greatly appreciated.

DEVELOPMENT OF AN *HOV SYSTEMS MANUAL*

SUMMARY

The National Cooperative Highway Research Program (NCHRP) Project 3-53, "Development of an HOV [High-Occupancy Vehicle] Systems Manual," accomplished two objectives. The first objective was the development of a comprehensive *HOV Systems Manual* that encompasses policy considerations, and planning, designing, marketing, implementing, operating, enforcing, and evaluating various types of HOV facilities. The second objective was to identify and recommend additional research needs related to HOV systems.

The *HOV Systems Manual*, which is published separately as *NCHRP Report 414* (*1*), represents the major product of this project. This final report documents the process used to develop the *HOV Systems Manual* (also referred to herein as the Manual), including the literature review, the survey of transportation professionals, and the identification of additional research needs. It also presents the implementation plan to help move the Manual quickly into practice and the suggested process for updating the Manual on a regular basis. Each of these elements is highlighted in this Summary, along with an overview of the Manual.

DEVELOPMENT OF THE *HOV SYSTEMS MANUAL*

State-of-the-Art Literature Review

A state-of-the-art literature review was conducted during the first phase of the project. Automated information retrieval networks, on-line databases, and local contacts of the research team were all used to obtain current reports and documents on guidelines, informal practices, and general knowledge relating to all aspects of HOV systems.

The results of the literature search identified a number of documents prepared by federal, state, and local agencies; universities; and consulting firms. Available documents related to developing HOV policies, and planning, designing, marketing, operating, enforcing, and evaluating HOV facilities on freeways and in separate rights-of-way were reviewed. Less information was available on arterial street applications, converting a general-purpose lane to an HOV lane, priority pricing with HOV facilities, and special-use lanes.

Survey of Transportation Professionals

A mail and telephone survey of transportation professionals was conducted during the first phase of the research project. The survey was used to obtain additional information on HOV projects, available reports and guidelines, critical issues, and gaps and weaknesses in current knowledge and practice. The survey also helped identify individuals interested in reviewing outlines and draft sections of the Manual.

A total of 50 surveys were received in response to the mailings sent to the TRB's HOV Committee members and representatives at state departments of transportation (DOTs) and transit agencies. The results indicated that agencies are more likely to use formal and informal guidelines with HOV facilities on freeways and in separate rights-of-way than on arterial streets. Formal design guidelines were most frequently noted, followed by signing and pavement markings, and enforcement provisions and practices.

Issues of concern identified by respondents were HOV policies, planning and demand estimation techniques, public involvement strategies, general-purpose lane conversions to HOV lanes, congestion pricing or priority pricing on an HOV facility, environmental impacts, design elements, marketing approaches, supporting facilities and services, and the use of Intelligent Transportation Systems (ITS) with HOV facilities. These issues related to HOV facilities in separate rights-of-way, on freeways, and on arterial roadways.

HOV SYSTEMS MANUAL

The *HOV Systems Manual*, which is a separate document, is comprised of 13 chapters and 3 appendices. The major topics addressed in each chapter are highlighted next.

Chapter 1—Guide to the *HOV Systems Manual*.
This chapter provides a quick guide for users of the *HOV Systems Manual* and describes the content and format of the remaining chapters.

Chapter 2—Introduction to HOV Facilities.
This chapter provides a summary of current issues, followed by a discussion of the HOV concept, the role HOV facilities can play in addressing some of these concerns, and the current status of HOV projects in North America. The different types of HOV facilities in use on freeways, in separate rights-of-way, and on arterial streets are highlighted.

Chapter 3—Policy Considerations with HOV Facilities.
This chapter describes the policies that may be adopted at the federal, state, regional, and local levels that can enhance the development and operation of HOV facilities. The role of HOV facilities in the overall transportation system, the evolution of HOV policies in North America, and examples of policies currently in use are highlighted.

Chapter 4—Planning HOV Facilities.
This chapter provides an overview of the steps involved in planning HOV facilities on freeways, in separate rights-of-way, and on arterial streets. Approaches appropriate for regional-, corridor-, and facility-level planning are presented. Available tools and techniques for demand estimation are summarized along with approaches for assessing the potential environmental impacts of HOV facilities.

Chapter 5—Operation and Enforcement of HOV Facilities on Freeways and in Separate Rights-of-Way.
Topics addressed in this chapter include the development of an operation and enforcement plan, HOV operational alternatives, access options, vehicle-eligibility and vehicle-occupancy requirements, transit operations, hours of operation, enforcement, incident management, and special operational consideration.

Chapter 6—Design of HOV Facilities on Freeways and in Separate Rights-of-Way
This chapter presents the design elements associated with HOV facilities on freeways and in separate rights-of-way. It includes information on the design process, the groups that are usually included in this process, vehicle design criteria, and the design features of barrier separated, concurrent flow, and contraflow HOV lanes, as well as different types of access treatments. Examples of cross-sections, signing and pavement markings, and other design elements are presented.

Chapter 7—Operation and Enforcement of Arterial Street HOV Facilities
This chapter describes the various approaches that can be used with arterial street HOV facilities, the advantages and disadvantages of different techniques, and the issues that may need to be considered with arterial street applications.

Chapter 8—Design of Arterial Street HOV Facilities
This chapter discusses the design elements associated with HOV facilities on arterial streets. It includes information on the steps in the design process, the groups that are usually included in this process, vehicle design criteria, and design features of various types of arterial street HOV facilities. Examples of cross-sections, signing and pavement markings, and other design elements are presented.

Chapter 9—Transit and Support Services and Facilities
This chapter presents the various transit service strategies and supporting fixed facilities that may be used with different types of HOV projects. These include transit stations, park-and-ride facilities, park-and-pool lots, and other supporting elements.

Chapter 10—Supporting Programs and Policies
This chapter discusses other supporting programs and policies that may contribute to the overall success of HOV facilities. These include regional rideshare programs, guaranteed-ride-home services, parking management and parking pricing, employer-based programs, growth controls, land use policies, and zoning ordinances.

Chapter 11—Implementing HOV Facilities
This chapter discusses techniques and approaches to meet these objectives. Involving the appropriate groups, developing an implementation plan, project phasing and sequencing, project bidding and contracting, managing traffic during construction, operating training, pre-operational testing, and other considerations are presented.

Chapter 12—Public Involvement and Marketing Programs
This chapter provides a comprehensive summary of the various elements to be considered in developing, implementing, and evaluating public involvement and marketing programs with HOV facilities. Topics covered include public participation,

market research, using in-house and consultant resources, marketing campaigns, funding marketing efforts, and evaluating marketing programs. Case study examples of successful and innovative public involvement techniques and marketing programs are also highlighted.

Chapter 13—Monitoring and Evaluating HOV Facilities
This chapter presents the elements to be considered in developing and implementing a comprehensive evaluation program. The processes for conducting an ongoing monitoring and evaluation program are presented and data collection techniques are discussed. Case study examples of evaluation programs with HOV facilities are also included.

Appendices
Three appendices are provided. These include a glossary of terms; a glossary of agencies, organizations, and legislation; and a summary of selected HOV facilities and proposed projects in North America.

IMPLEMENTATION PLAN AND UPDATING THE MANUAL

Implementation Plan

A proposed plan was developed outlining the approaches and techniques to help ensure that the Manual is quickly made available to practitioners and is incorporated into everyday use and practice. The proposed plan provides a coordinated and comprehensive technology transfer process necessary to advance the state-of-the practice related to all aspects of HOV systems. The proposed implementation plan is comprised of the following elements. Additional resources will be needed to implement some of these elements.

- Marketing the *HOV Systems Manual;*
- Distributing the *HOV Systems Manual;*
- Using the *HOV Systems Manual* at national, state, and local training sessions;
- Maintaining the HOV Web Site;
- Publishing the *HOV Systems Manual* on CD-ROM;
- Using video to support the *HOV Systems Manual;*
- Distributing the Manual at national conferences; and
- Using the *HOV Systems Manual* in graduate and undergraduate courses.

Updating the Manual

Recommendations for updating the *HOV Systems Manual* on a regular basis are also included in this final report. The recommended process contains two major components. First, the results of new research should be added to the Manual. Second, the Manual should be reviewed every 5 years to determine major update needs. The TRB HOV Systems Committee should play a key role on both these activities.

It is recommended that the results of the additional research projects identified previously and other relevant studies be incorporated into the Manual on an ongoing basis. To facilitate the update process, and to ensure conformity, it is recommended that a new or revised section of the *HOV Systems Manual* be one of the required deliverables for every research project. This requirement should be included in the request for proposal (RFP) or other statement of work issued on future research projects.

The updated sections should follow the format of the current manual. To help ensure the quality and usefulness of the updated sections, it is recommended that the TRB HOV Committee review each new or revised section prior to publication.

In addition, it is recommended that the TRB HOV Systems Committee review the full *HOV Systems Manual* every 5 years. This review should focus on identifying new and emerging trends, developing additional research problem statements, and updating project information. The results of this review would be specific recommendations on updating chapters or sections and additional research studies. These recommendations would be provided to TRB, NCHRP, TCRP, FHWA, FTA, and other agencies for initiating the update process.

CHAPTER 1

INTRODUCTION AND RESEARCH APPROACH

This final report documents NCHRP Project 3-53, "Development of an HOV Systems Manual." The major product of the research study is the *HOV Systems Manual (1)*, which is published separately as *NCHRP Report 414*. As a result, this final report highlights only the major activities conducted in the project and the implementation plan. This chapter summarizes the research problem statement, objectives, scope, and approach. Chapter 2 presents the findings from the literature review and the survey of HOV practitioners. Chapter 3 presents the gaps and weaknesses in current knowledge and existing practices related to all aspects of HOV systems. (The first three chapters were provided previously in the interim report.) The last chapter highlights the development of the *HOV Systems Manual* and the updated implementation plan for moving the Manual into practice.

PROBLEM STATEMENT AND RESEARCH OBJECTIVES

Traffic congestion in metropolitan areas represents a significant problem that is receiving increased attention today. Concerns about declining urban mobility, increased air pollution, and wasted resources have been voiced on many fronts. The cost of congestion, which has been estimated—based only on the costs associated with fuel consumption and delay—at some $4 billion annually for the 50 largest urban areas in the country (*2*), is limiting the economic development potential of many areas. Complicating the situation further, most metropolitan areas are facing congestion issues in a time of limited resources, both in terms of available funding for the expansion of highway and transit systems and available land for new construction.

Realizing that there is no single solution, transportation professionals and decision makers have been pursuing a variety of techniques and approaches to address these problems. High-occupancy vehicle (HOV) facilities represent one viable technique being used in many areas to respond to these concerns. HOV facilities, which offer priority treatments to buses, vanpools, and carpools, focus on increasing the person-movement, rather than vehicle-movement, of a roadway or travel corridor. At the time of this writing, approximately 52 HOV projects are in operation on freeways or in separate rights-of-way in 24 North American metropolitan areas. Additional HOV lanes are in operation on arterial streets, and many more HOV projects are in various stages of development.

Existing HOV facilities have been designed and implemented in response to local problems, needs, opportunities, and policy considerations. As a result, a variety of design treatments have been and are being used. In addition, the approaches used to implement, operate, market, and enforce HOV lanes varies greatly, along with the nature and extent of support facilities and services. Currently, both formal and informal guidelines and practices are available for transportation professionals interested in different aspects of HOV systems. These include manuals developed at the local level (*3,4,5*), the state level (*6,7,8*), and the federal level (*9*), as well as those completed by national organizations (*10,11,12*) and consulting firms (*13*).

As a result of the evolving nature of HOV systems, differences exist among many of the current guidelines and practices. An up-to-date comprehensive document that addresses all aspects of developing policies, and planning, designing, marketing, operating, enforcing, and evaluating HOV facilities does not exist. This research study was conducted to help meet this need.

NCHRP Project 3-53 focused on two objectives. The major objective of the research study was the development of a comprehensive *HOV Systems Manual* that addresses all types of HOV facilities. The manual incorporates current guidelines and practices related to all aspects of HOV systems. Elements addressed include policy considerations, and planning, designing, marketing, implementing, operating, enforcing, and evaluating HOV systems. Information is also included on support facilities, services, policies, and programs. These elements are presented as a systematic process to ensure the coordinated development of all elements of an HOV system.

The second objective of the project was to identify and recommend future research efforts related to HOV systems. This aspect of the study examined the gaps and weaknesses in current knowledge and identified critical issues that need to be resolved to enhance the effectiveness of existing and future HOV applications. The results of this analysis can be used by the NCHRP, TRB, AASHTO, the Institute of Transportation Engineers (ITE), and other groups. Accomplishing this objective will provide for a multifaceted, ongoing HOV

systems research program that addresses critical issues to advance the state of the practice.

SCOPE OF STUDY

This research study is comprised of two phases. The first phase, which was documented in an interim report and in Chapters 2 and 3 of this report, focused on assessing the current knowledge and practice relating to all aspects of HOV systems and identifying gaps and weaknesses. These objectives were accomplished through a review of available technical reports, manuals, guidelines, and articles, and a survey of HOV practitioners in North America. The results of these activities are summarized in Chapter 2. The results of the literature review and the surveys were then used to identify the gaps and weaknesses in current knowledge and practice related to all aspects of HOV systems. These gaps and weaknesses are examined in Chapter 3.

The development of the *HOV Systems Manual* occurred in the second phase of the research study. The major activities completed in the development of the Manual are highlighted in Chapter 4, which also contains the implementation plan for transferring the Manual quickly into practice. This final report and the *HOV Systems Manual* represent the completion of this research project.

RESEARCH APPROACH

The research approach in the first phase of this study focused on four major activities. First, a state-of-the-art literature review was conducted to obtain information on current practices related to developing HOV policies, and planning, designing, implementing, marketing, operating, enforcing, and evaluating the various types of HOV facilities. The research team used automated information retrieval networks, on-line databases, and local contacts to obtain current information on existing practices.

Second, a survey was conducted to obtain additional information from representatives at state departments of transportation (DOTs), transit agencies, rideshare organizations, metropolitan planning organizations (MPOs), consulting firms, federal agencies, local jurisdictions, and other groups. Fifty completed surveys were returned and analyzed.

Third, the information obtained from the literature review and the surveys was analyzed by the research team. Formal guidelines and informal practices were identified, along with common themes, concerns, and issues. The gaps and weaknesses in current knowledge and practice emerged from this analysis.

Finally, the information obtained and analyzed in the previous steps was used to develop the proposed format and detailed outline for the manual, the guide for practitioner involvement, the implementation plan, and the revised Phase Two work plan and schedule. The draft outline provided in the proposal, which was initially developed by the TRB HOV Systems Committee, was used as the starting point for the detailed *HOV Systems Manual.* Additions and revisions were made in the draft outline, however, based on the results of the literature review and the survey of practitioners.

The interim report was reviewed by the NCHRP Project Panel. Based on the positive response from the Panel, NCHRP authorized the research team to proceed with the second phase of the study. The comprehensive approach used in the first phase established a sound base for the Phase Two activities. The major activity during Phase Two was the actual development of the *HOV Systems Manual.* Additional information on some topics and projects was obtained and analyzed for incorporation into the Manual. Individual chapters were prepared and provided to the NCHRP Panel and to individuals who had expressed interest in assisting with the study. The chapters were revised on the basis of the review comments, and the final draft *HOV Systems Manual* was prepared for final review by the NCHRP Panel.

CHAPTER 2

FINDINGS

STATE-OF-THE-ART LITERATURE REVIEW

This chapter documents the results of the state-of-the-art literature review conducted as part of the first phase of the research project. Automated information retrieval networks, on-line databases, and local contacts of the research team were all used to obtain current reports and documents on guidelines, informal practices, and general knowledge relating to all aspects of HOV systems. Additional information was also obtained through the survey results of practitioners discussed later in this chapter. The results of the literature review are presented in the following 10 general categories:

- HOV facility policy considerations;
- HOV facility planning;
- HOV facility design;
- HOV facility marketing;
- HOV facility operations;
- HOV facility enforcement;
- HOV facility implementation;
- Support facilities, services, policies, and programs;
- Environmental and air quality impacts; and
- HOV facility evaluation and research needs.

The focus of the literature review is on formal guidelines, informal practices, and studies assessing the state of the practice and general knowledge related to these 10 categories. Although reports on specific HOV feasibility studies, major investment studies, and other related projects were examined, these did not constitute the major focus of the literature review. The results of the literature review are summarized next. Significant reports and documents are highlighted in each of the 10 categories. A more extensive bibliography is provided in Appendix A. The gaps and weaknesses in current practice and knowledge are discussed in Chapter 3.

HOV Facility Policy Considerations

A few states have developed policies relating to HOV facilities. The approaches used in four states are highlighted in this section.

Arizona Department of Transportation, Maricopa Association of Governments, and Regional Public Transportation Authority—The *High-Occupancy Vehicle Facilities Policy Guidelines and Plan for the MAG Freeway System* (*14*) was prepared for these three agencies. The first phase of this project developed policies to guide HOV facilities—including HOV lanes, exclusive freeway-to-freeway ramps and freeway-to-arterial ramps, park-and-ride lots, and bus stations—on the freeway system in the Phoenix area. The HOV mission statement, HOV commitment statement, and policies for roles and responsibilities were adopted by all three agencies. The policies for roles and responsibilities address the decision-making and coordination process, the planning and programming process, implementation and funding, the monitoring and evaluation process, marketing, and preservation of capacity for HOV facilities. A second phase of the study developed a recommended systemwide HOV plan for the area.

Missouri Highway and Transportation Department—The *Policy on High-Occupancy Vehicle Facilities* (*15*) presents a series of general guidelines for use in planning, designing, and operating HOV facilities in Missouri. The policies were developed by an HOV Task Force and were adopted by senior management of the Missouri Highway and Transportation Department (MHTD). The policies establish general criteria relating to congestion, travel time, impact on mixed-flow lanes, HOV volumes, person movement, local support, enforcement, safety, cost, support facilities and programs, environmental factors and bus service to guide the consideration of HOV on freeways and arterials.

New York State Department of Transportation (NYSDOT)—The NYSDOT uses the guidelines contained in the 1985 report, *Proposed Warrants for High-Occupancy Vehicle Treatments in New York State* (*16*), for considering HOV projects. The general guidelines focus on existing traffic volumes, level of transit service, congestion, person-movement, travel time savings, downtown conditions, and other factors affecting the success of HOV treatments. These general guidelines have been expanded and refined for use in assessing the potential of site-specific HOV projects.

Washington State Department of Transportation—The *Washington State Freeway HOV System Policy* (*17*) outlines the objectives of the HOV system in the state and provides policy guidelines relating to different elements of the HOV system. Elements addressed in the policies include minimum thresholds for HOV lanes, agency and mode coordination, carpool definitions, hierarchy of HOV facility development, hours of operation, enforcement, lane location (inside vs. outside) and separation, general-purpose lane conversion, HOV system performance, promotion, design standards, land use coordination, and supporting programs, services, and facilities.

HOV Facility Planning

Overall Planning Documents

The following four documents provide a general overview of planning for various types of HOV facilities. All four reports include not only planning considerations, but also cover the design and operation of HOV facilities.

California Department of Transportation (Caltrans)—The *High-Occupancy Vehicle Guidelines for Planning, Designing, and Operations* (*6*) provides a "how to" document for planners, designers, and operators of mainlane HOV facilities. It was developed in response to requests from Caltrans Districts for guidelines to provide statewide consistency and uniformity with HOV facilities. The section on HOV planning includes Caltrans policies related to HOV facilities, planning factors and criteria, demand modeling, and regional system planning.

NCHRP—*NCHRP Synthesis 185—Preferential Lane Treatments for High-Occupancy Vehicles* (*12*) provides a summary of current planning practices for HOV facilities. It describes the general conditions supporting consideration of HOV projects, demand estimation procedures, and planning criteria.

Parsons Brinckerhoff—*High-Occupancy Vehicle Facilities: A Planning, Design, and Operations Manual* (*13*) starts with a discussion of different planning techniques. A three-step process is outlined focusing on examining the conceptual viability of a facility, developing and analyzing alternatives, and developing the recommended alternative. A number of activities are included in each of these three steps to provide an easy to use guide for examining HOV alternatives.

Texas Department of Transportation (TxDOT)—The *Revised Manual for Planning, Designing, and Operating Transitway Facilities in Texas* (*7*) provides general guidelines for planning HOV facilities in Texas. The section on planning discusses identifying potential candidate freeway segments, locating HOV lanes, and demand estimation procedures. It also contains similar planning guidelines for supporting facilities such as park-and-ride lots, park-and-pool lots, and transit centers.

HOV Demand Estimation

Techniques for estimating the demand for various types of HOV facilities are included in the four documents noted previously. In addition, the following study is being conducted for the Federal Highway Administration (FHWA) to develop a better HOV demand estimation model.

FHWA—"Predicting the Demand for High-Occupancy Vehicle Lanes" was a 2-year study sponsored by FHWA. The project developed a methodology and a microcomputer software model for analyzing HOV lane demand and operations. A number of reports were prepared as part of the study, along with the microcomputer software program (*18,19,20,21*).

Area and Project-Specific Planning Studies

A number of studies and reports were identified during the literature review that address regionwide HOV planning and the planning and evaluating of HOV facilities on a specific freeway or travel corridor. Documents from the Seattle area (*22,23*,24), New Jersey (*25*), Denver (*26*), Dallas (*27*), and Pittsburgh (*28*) represent a few examples of the types of planning studies being conducted throughout the country.

Most of these studies focus on HOV facilities on freeways. A few examples of studies focusing on arterial street HOV lanes and take-a-lane assessments were identified, however. The arterial street HOV assessments in Snohomish County and the Seattle area (*29*) and the Toronto area in Canada (30) provide two examples. A general assessment of public attitudes toward converting general-purpose lanes to HOV lanes has been conducted in California (*31*) and more site-specific analyses have been undertaken in the Seattle area (*32,33*).

HOV Facility Design

General HOV Design Guidelines

The following documents address the design requirements of various types of HOV facilities.

AASHTO—The AASHTO *Guide for the Design of High-Occupancy Vehicle Facilities* (*10*) focuses primarily on design guidelines for new and improved HOV facilities. The design features of different HOV treatments on freeways, in separate rights-of-way, and on arterial streets are discussed. Design features addressed include design speeds,

cross section widths, access, lane markings, control devices, enforcement areas, and terminal facilities.

Caltrans—The *High-Occupancy Vehicle Guidelines for Planning, Designing, and Operations* (*6*) contains a chapter on the design of different types of HOV facilities. A set of general design criteria are presented for various HOV applications and both preferred and acceptable geometric configurations are outlined.

Institute of Transportation Engineers (ITE)—The ITE *Design Features of High-Occupancy Vehicle Lanes* (*11*) provides a review of available information on the elements and criteria necessary for the safe and effective operation of HOV facilities. The scope encompasses design elements and their functions, and the criteria for the safe and effective operation of high-speed HOV facilities. The document provides a summary of HOV lane design manuals, HOV lane designs, current practices for both exclusive and concurrent flow HOV lanes on freeways, existing HOV signing and pavement markings, and priority entry ramp design considerations.

Ministry of Transportation, Ontario—Two HOV design guides have been developed for the Ministry of Transportation in Ontario: *Operational Design Guidelines for High-Occupancy Vehicle Lanes on Arterial Roadways* (*34*) provides an overview of HOV networks and strategic planning and design guidelines for arterial HOV lanes. Design features associated with different lane treatments, queue bypasses, intersection treatments, signage, enforcement, and transit provisions are addressed. *Operational Design Guidelines for High-Occupancy Vehicle Lanes on Ontario Freeways* (*35*) examines planning and operational issues, supporting HOV priority programs, and presents freeway HOV design guidelines. Design features related to different types of lanes, ingress and egress provisions, and other elements are outlined.

Parsons Brinckerhoff—The *High-Occupancy Vehicle Facilities: A Planning, Design, and Operations Manual* (*13*) includes an extensive section on HOV design considerations. The section on HOV design includes typical cross sections for different types of lanes and supporting facilities. It also discusses signing and pavement markings, incident and maintenance consideration, and design elements of enforcement areas.

Regional Municipality of Ottawa-Carleton (O-C Transpo)—The *Transitway Design Manual* (*5*) developed by O-C Transpo outlines the design guidelines used for the transitway system in Ottawa, Ontario. These guidelines address bus-only facilities located in separate rights-of-ways, as well as some elements related to arterial street applications and support facilities.

TxDOT—The *Revised Manual for Planning, Designing, and Operating Transitway Facilities in Texas* (*7*), includes a major section on design criteria. Elements addressed include alignments, gradients, clearances, cross section widths, and special features of barrier-separated HOV lanes, exclusive access ramps, park-and-ride lots, and transit centers.

Washington State Department of Transportation—*Design Manual—Section 1050, High-Occupancy Vehicle Priority Treatment* (*8*) addresses design features related to different types of HOV lanes and supporting facilities.

Project-Specific Design Reports

As with the project-specific planning reports noted in the previous section, studies examining alternative design treatments and final design documents are available on HOV projects throughout North America. Examples of design reports completed by members of the research team and other groups were examined during the literature review.

HOV Facility Marketing

General Marketing Guidelines

The following report prepared for FHWA provides overall directions for planning and implementing marketing programs with HOV facilities.

FHWA—The *HOV Lane Marketing Manual* (*36*) was prepared by SYSTAN, Inc. in association with the Roanoke Company and Pacific Rim Resources. This manual was developed to provide marketing and HOV professionals with practical guidelines for improving the public awareness, understanding, acceptance and use of HOV lanes. The manual discusses planning and implementing an HOV facility marketing campaign, as well as monitoring and evaluating both the HOV project and campaign. It also contains a number of case studies to illustrate the concepts discussed.

Project-Specific Marketing Program

A few reports are available describing HOV project-specific marketing programs, and presentations have been made at HOV conferences on different marketing efforts. Marketing materials, including brochures, direct mail pieces, newspaper advertisements, radio and television commercials, and other promotional material are available on a number of projects.

HOV Facility Operations

General Operation and Guidelines

A few of the manuals described previously also address operational considerations of HOV facilities. These are briefly summarized next.

Caltrans—The *High-Occupancy Vehicle Guidelines for Planning, Designing, and Operations* (*6*) provides a chapter on HOV operations. The chapter summarizes the operating characteristics of different types of HOV facilities, alternative operating hour scenarios, vehicle and vehicle occupancy requirements, and incident management.

Parsons Brinckerhoff—Parson Brinckerhoff's *High-Occupancy Vehicle Facilities: A Planning, Design, and Operations Manual* (*13*) includes a chapter on the operation of various types of HOV facilities. Topics addressed include operational objects and alternatives, vehicle and vehicle occupancy requirements, hours of operation, enforcement, incident management, and safety.

TxDOT—The *Revised Manual for Planning, Designing, and Operating Transitway Facilities in Texas* (*7*) addresses operational considerations in a separate chapter. The same elements noted with the two previous documents are covered.

Issues and Project-Specific Reports

Studies have been conducted throughout the country on specific topics and issues related to the operation of HOV facilities. These include studies of safety concerns, motorcycle use of HOV lanes, and changing occupancy levels. A few of the recent reports available on these topics are summarized next.

California Polytechnic State University—The report, *High-Occupancy Vehicle Lane Safety* (*37*), documents the results of a study conducted in 1992 by California Polytechnic State University for Caltrans. The study included a cross-sectional comparison of freeway sections with HOV lanes and similar freeway sections without HOV lanes in San Diego, Orange County, Los Angeles, and San Francisco. A disaggregate statistical analysis of recent accident data was conducted, along with video assessments of traffic operations. The study concluded that "accident rates on freeways with HOV lanes are sensitive to variations in traffic congestion in much the same manner that accident rates are influenced by congestion on non-HOV facilities . . . and no major systematic differences in accidents' lane locations or other factors which could be attributed directly to the presence of the HOV facility." (*37*)

Virginia Transportation Research Council—*The Effect of Motorcycle Travel on the Safety and Operations of HOV Facilities in Virginia* (*38*) was conducted by the Virginia Transportation Research Council for the Virginia Department of Transportation (VDot). The study found that motorcycles accounted for some 3 percent of the annual HOV lane vehicles and that over a 2-year period only five motorcycle crashes were reported on the eight facilities. As a result, the study recommends that motorcycles be allowed to continue to use the HOV lanes.

TxDOT and Texas Transportation Institute (TTI)—The change in vehicle occupancy requirements on the Katy Freeway (I-10 West) HOV lanes has been monitored and evaluated over the years. This ongoing assessment has included the examination of the variable time-of-day occupancy requirement currently in effect (*39*).

University of Washington and TTI—The Washington State DOT sponsored a study conducted by these two organizations to assess the change in the vehicle occupancy requirement (from 3+ to 2+) on the I-5 North HOV lanes in Seattle (*40*).

HOV Facility Enforcement

General Enforcement Guidelines

Three of the manuals described previously include sections or full chapters on enforcing HOV facilities. Other guidelines highlight enforcement considerations in chapters on planning, designing, and operating HOV facilities. The following manuals provide the most extensive discussion of enforcement issues.

Caltrans—The *High-Occupancy Vehicle Guidelines for Planning, Designing, and Operations* (*6*) includes a chapter on HOV enforcement. The chapter discusses the role of enforcement, violation rates with different types of facilities, alternative enforcement techniques, design elements, and other enforcement considerations.

Parsons Brinckerhoff—*High-Occupancy Vehicle Facilities: A Planning, Design, and Operations Manual* (*13*) addresses enforcement in the chapters on planning, operations, and design. In the planning chapter, the need for early involvement of enforcement personnel is noted and the development of an enforcement plan is discussed. Operational and design considerations relating to enforcement are included in the other two chapters.

TxDOT—The *Revised Manual for Planning, Designing, and Operating Transitway Facilities in Texas* (*7*) also includes a discussion of enforcement considerations relating to planning, designing, and operating HOV facilities.

Issues and Project-Specific Reports

Enforcement concerns related to HOV facilities have been discussed at HOV conferences over the years and studies have been undertaken of specific issues related to enforcement. These include assessments of specific enforcement efforts, such as the HERO program in Seattle (*41*), as well as the use of advanced technologies to assist with enforcement (*42,43*).

HOV Facility Implementation

General Guidelines

A few of the guidelines described above address various aspects related to implementing HOV projects. The following documents provide the best general discussion of implementation considerations.

Parsons Brinckerhoff—*High-Occupancy Vehicle Facilities: A Planning, Design, and Operations Manual* (*13*) includes a chapter on implementation. Topics covered briefly in the chapter include the bidding process, scheduling and managing traffic during construction, groups to involve in the process, ongoing public awareness, and evaluating project effectiveness.

Project-Specific Implementation Experience

The techniques used to implement five case study HOV projects in Houston, Orange County, Seattle, Pittsburgh, and Washington, D.C./Northern Virginia, are documented in the TTI report, *High Occupancy-Vehicle Project Case Studies: History and Institution Arrangements* (*44*), prepared as part of the FTA-sponsored national assessment of HOV facilities. Additional information on implementation of specific HOV projects has been presented at TRB annual meeting sessions and at HOV conferences over the years.

Support Facilities, Services, Policies, and Programs

General Guidelines

Many of the general documents described thus far related to planning, designing, and operating HOV facilities also address support facilities, services, policies, and programs. The following guidelines and reports address various aspects of supporting facilities, services, policies, and programs relating to HOV facilities in more detail.

AASHTO—The AASHTO *Guide for the Design of Park-and-Ride Facilities* (*45*) addresses site selection and design of park-and-ride facilities. Elements covered in the site selection process include defining the study area, and site selection criteria, techniques, and evaluation procedures. The physical design elements of different types of park-and-ride facilities are addressed, along with lighting, landscaping, and other considerations. Operating and maintaining park-and-ride lots are also addressed.

FHWA—*Park-and-Ride Facilities—Guidelines for Planning, Design, and Operation* (*46*) provides an overview of park-and-ride facilities and contains specific chapters on developing program goals and objectives, planning and locating, designing, and implementing and operating park-and-ride lots.

NCHRP—*NCHRP Synthesis 213*, "Effective Use of Park-and-Ride Facilities" (*47*), provides an overview of planning, locating, designing, and operating park-and-ride lots. Additional supporting elements, such as HOV lanes, travel demand management programs, land use and growth management techniques, and ITS are also covered.

Environmental and Air Quality Impacts

The following reports and articles highlight the recent discussion concerning the impacts of HOV facilities on the environment and air quality. As discussed in more detail in the next chapter, these are areas where more research is needed to better understand the possible beneficial, as well as negative, impacts of HOV facilities on the environment and air quality.

Cambridge Systematics, Inc., COMSIS, and others—*Transportation Control Measure Information Documents* (*48*), was prepared for the Environmental Protection Agency (EPA) by Cambridge Systematics, Inc.; COMSIS; Deakin, Harvey, Skabardonis; K. T. Analytics, Inc.; and the Georgia Institute of Technology in 1992. Information is provided on 16 categories of transportation control measures. HOV facilities comprise one of the categories. Information on the transportation, emissions, and air quality impacts of each category is provided, along with estimates of capital and operating expenses, requirements to achieve effective implementation, and a bibliography.

The Chesapeake Bay Foundation—*Rethinking High-Occupancy Vehicle Facilities and the Public Interest* (*49*), questions the benefits of HOV lanes. The report suggests that the construction of new HOV lanes, rather than the conversion of an existing general-purpose lane to an HOV lane, may actually have negative impacts on air quality and other environmental elements.

Robert Johnston and Raju Ceerla—"The Effects of New High-Occupancy Vehicle Lanes on Travel and Emissions" (*50*), examines past modeling efforts and travel demand simulations to demonstrate that new HOV lanes may increase vehicle kilometers of travel and increase emissions relative to other transit alternatives. Enhancements to the travel demand modeling process are suggested to improve the ability to estimate possible impacts.

Rajendra Jain—The article, "Transportation and the Environment—HOV Experience in Connecticut" (*51*), examines the anticipated impact on air quality and other environmental factors from HOV lanes in the Hartford area. It notes that beneficial reductions in volatile organic compounds (VOCs) and nitrogen oxides (NO_x) are anticipated from reduced vehicle dwell times in congested traffic.

Modeling Techniques for Estimating Air Quality and Environmental Impacts

Although several cautions are given throughout the literature with regard to the accuracy one should expect with the current modeling techniques, several modeling techniques are available for use in estimating the air quality and environmental impacts of HOV facilities. The most common approaches use macroscopic (e.g., FREQ11) or microscopic (e.g., NETSIM, FRESIM) models for analyses. Such models allow analyses of fuel consumption and emission rates based upon different geometric conditions and travel volumes that would be experienced with various alternatives, including HOV lanes. These and other techniques have been used with specific HOV projects. Information on the use of these techniques has been presented at TRB annual meeting sessions, HOV conferences, and other workshops.

NCHRP Project 25-11, "Development of a Modal-Emissions Model," which is being conducted by the University of California at Riverside, is developing a more accurate emissions model that is sensitive to cruise, acceleration, deceleration, and idle conditioning. A useable modal-emissions model is expected to be available by mid- to late-1998. Related work is also underway at the Georgia Technical Institute sponsored by the EPA.

HOV Facility Evaluation and Research Needs

Evaluating HOV Projects

The following report, prepared for the FTA, provides general guidelines for evaluating the effectiveness of HOV facilities.

FTA—The report, *Suggested Procedures for Evaluating HOV Lanes* (*52*), was prepared by TTI as part of the 3-year assessment of HOV projects in North America funded by FTA through TxDOT. The report presents the results of the state-of-the-art review of evaluation practices used with HOV lane projects in North America. The review considers HOV projects on both freeways and separate rights-of-way. The report presents a set of suggested objectives for HOV facilities and procedures for before-and-after evaluations of freeway HOV facilities and ongoing monitoring activities. These include specific evaluation measures, measurement techniques, and data collection methodologies.

Project-Specific Evaluations

A number of before-and-after evaluations have been conducted of HOV projects in North America. Many of these were examined as a part of the previously noted study and are included in the referenced report. Examples of the more comprehensive assessments are highlighted next.

Houston—An extensive program for monitoring and evaluating the HOV lane system in Houston has been underway for a number of years. The evaluation program is sponsored by TxDOT, in cooperation with Houston METRO, and conducted by TTI. The Houston program represents the most comprehensive, continuous HOV monitoring effort in the country. Vehicle and occupancy counts, park-and-ride lot usage, travel times, user and non-user surveys, accidents data, and violations data are collected and analyzed on a regular basis. Annual reports have been prepared documenting the results of the evaluation (*39*).

Minneapolis—A comprehensive assessment has been conducted on the I-394 HOV facility in Minneapolis. The multiyear evaluation was sponsored by the Minnesota DOT and conducted by SRF, Inc. The evaluation covered the period from 1984 to 1995. Information was collected before construction started, during the interim operation, and after completion of the full facilities. The final report covers all three time periods (*53*).

Seattle—A number of evaluations have been conducted on the HOV facilities in Seattle. These include ongoing

monitoring efforts (*54*) and special studies (*40*). The various reports provide a good database on the use and impact of the HOV lanes in the area.

Washington, D.C./Northern Virginia—Periodic studies have also been conducted on the HOV lanes in Washington, D.C. and Northern Virginia. For example, a monitoring and evaluation program was conducted of the Shirley Highway HOV lanes during the first years of operation (*55*). Other studies have also been conducted to assess changes in operating hours and vehicle occupancy requirements (*56*).

Research Needs

TRB HOV Systems Committee—The TRB HOV Systems Committee developed the *Program of Research for HOV Systems* (*57*) in 1994 and 1995. The program recommends 18 separate, but interrelated and coordinated, research studies to address identified deficiencies in planning, designing, operating, and enforcing HOV facilities. The research being conducted in this study, and the development of an *HOV Systems Manual*, was one of the initial studies recommended in the program. Other research needs identified in the document are also being addressed. These include the marketing manual, the HOV demand estimation study, and the training courses described previously. All of these projects are sponsored by FHWA.

Other research needs related to planning and design identified in the program focus on analyzing the air quality impacts of HOV facilities, assessing actual versus perceived travel time savings, examining key factors for successful HOV projects, developing guidelines for lane conversion projects, and addressing specific design concerns. Operation and enforcement research topics focus on effective enforcement procedures, eligibility and operational definitions, and the safety of various HOV treatments. Arterial street research topics include assessing the various types of projects and developing appropriate monitoring and evaluation techniques.

The TRB HOV Systems Committee continues to monitor and update the research program. A number of new topics have been identified by the committee and other groups for inclusion. As discussed more extensively in the next chapter, these include issues related to lane conversion, congestion pricing with HOV facilities, ITS, innovative financing, and other operational concerns.

SURVEY OF PRACTITIONERS

A mail and telephone survey was conducted as part of the first phase of this project. The survey was designed to meet a number of objectives. These included obtaining updated information on HOV projects; current practices relating to developing policies, planning, designing, marketing, implementing, operating, enforcing and evaluating HOV facilities; critical issues; gaps and weaknesses in current knowledge; and areas for additional research. The survey was also used to help identify additional items for inclusion in the manual and interest in participating in the practitioner review process.

Survey Methodology

The survey was conducted to obtain information from practitioners in North America responsible for various aspects of HOV facilities. A draft survey was developed by members of the research team and provided to the NCHRP panel for review. The survey was finalized on the basis of the comments from the panel and approval from NCHRP staff.

A copy of the survey form is provided in Appendix B. The survey was mailed to approximately 180 representatives in state DOTs, transit agencies, MPOs, federal agencies, cities and counties, consulting firms, and other groups. A number of sources were used to identify individuals for the surveys. These included the TRB HOV Systems Committee and Friends of the Committee listing, the mailing list for the HOV Marketing Manual, and contacts of the research team members. In some cases, multiple surveys were sent to one organization. For example, 38 individuals from 11 state departments of transportation and transit agencies received surveys.

The surveys were mailed in early November 1995. Individuals were given the option of completing and returning the survey or providing the information over the telephone. Most people elected to return completed surveys, but some information was taken over the telephone. TTI researchers also made follow-up calls to individuals who did not respond to the initial request.

A total of 50 surveys were completed. The return rate represents approximately 40 percent of the agencies or groups included in the survey. The agencies and groups represented by the completed surveys are identified in Table 1. Appendix C provides a listing of the individuals responding to the surveys. The survey results are summarized in the next section and analyzed in more detail in Chapter 3.

Survey Results

Guidelines

Individuals were asked to identify formal guidelines, as well as informal guidelines or practices, in use in their areas related to HOV facilities on freeways, in separate rights-of-way, and on arterial streets. Table 2 provides a

TABLE 1 Survey Respondents

Agency/Organization	Number	Percentage
State DOT	20	40%
Transit	19	38%
City/County	4	8%
MPO	2	4%
FHWA/FTA	1	2%
Consulting Firm	2	4%
Toll/Turnpike	1	2%
Environmental	1	2%
Total	50	100%

summary of the topics covered by these current formal and informal guidelines on freeways and in separate rights-of-way. Table 3 presents similar information for arterial street HOV facilities.

The information highlighted in these tables indicates that agencies are more likely to use formal and informal guidelines with HOV facilities on freeways and in separate rights-of-way than with those on arterial streets. Formal design guidelines were most frequently noted by respondents, followed by signing and pavement markings and enforcement practices and provisions. Other topics covered by formal guidelines, noted by at least 10 respondents, included planning, public involvement, funding and financing, operations, incident management, support facilities, and energy and air quality impacts. Although these topics are also covered by informal practices, a number of other subjects are addressed by informal guidelines. The informal practices noted by at least 10 respondents focused on policy considerations,

TABLE 2 Formal and informal guidelines related to HOV lanes on freeways and in separate rights-of-way

Topic	Formal Guidelines	Informal Practices
• HOV policy considerations	15	12
• Planning	11	16
• Public involvement	14	10
• Demand estimation	9	15
• Funding/financing	12	11
• Design	24	7
• Converting general-purpose lanes to HOV lanes	8	10
• Congestion pricing on HOV lanes	4	6
• Managing demand-vehicle occupancy levels	9	14
• Hours of operation	10	16
• Marketing	5	15
• Operations	10	11
• Incident management	16	9
• Signing and pavement markings	21	6
• Enforcement practices and provisions	17	10
• Support facilities (park-and-ride lots, transit centers, etc.)	12	15
• Transit services	7	10
• TDM	7	10
• ITS	6	7
• Energy and air quality impacts	13	6
• Other environmental impacts	10	6
• Evaluation	7	17
• Research	4	13

TABLE 3 Formal and informal guidelines related to arterial street HOV lanes

Topic	Formal Guidelines	Informal Practices
• HOV policy considerations	6	8
• Planning	5	6
• Public involvement	4	6
• Demand estimation	5	4
• Funding/financing	5	5
• Design	9	2
• Converting general-purpose lanes to HOV lanes	3	2
• Congestion pricing on HOV lanes	1	3
• Managing demand-vehicle occupancy levels	2	4
• Hours of operation	2	4
• Marketing	2	3
• Operations	3	3
• Incident management	1	3
• Signing and pavement markings	8	2
• Enforcement practices and provisions	4	3
• Support facilities (park-and-ride lots, transit centers, etc.)	2	3
• Transit services	2	4
• TDM	2	2
• ITS	1	1
• Energy and air quality impacts	3	3
• Other environmental impacts	2	4
• Evaluation	3	4
• Research	2	4

planning, demand estimation, funding and financing, managing demand, operating hours, marketing, support facilities, and evaluations.

As shown in Table 3, fewer formal guidelines and informal practices are in use with arterial street HOV facilities. Only 12 respondents indicated the use of either formal guidelines or informal practices related to arterial street HOV facilities. Guidelines addressing design requirements and signing and pavement markings on arterial street HOV lanes were most frequently noted by respondents, while HOV policy considerations, planning, and public involvement were the most commonly reported informal practices. Five transit agency representatives reported arterial street guidelines, compared to three state departments of transportation staff members, and two representatives from local communities. The other two individuals noting arterial street guidelines were from FHWA and an environmental group.

Issues and Concerns

Respondents were provided with two opportunities to identify the major issues and concerns related to HOV facilities in their area. First, the same list of topics presented in previous questions were repeated, and individuals were asked to identify those representing major problems or concerns in their areas. An open-ended follow-up question requested information on the top new or ongoing concerns in their area.

Table 4 summarizes the responses to the first question. As shown in the table, issues were more frequently identified with HOV lanes on freeways and in separate rights-of-way than with those on arterial streets. The top three concerns cited with HOV lanes on freeways and in separate rights-of-way were converting general-purpose lanes to HOV lanes, congestion pricing on HOV lanes, and enforcement practices and provisions. Other issues identified related to policy considerations, planning, public involvement, demand estimation, funding and financing, design, managing demand, marketing, transit services, and evaluations.

Fewer respondents identified major concerns associated with arterial street HOV applications. Issues identified by at least five respondents included HOV policy considerations, demand estimation, converting general-purpose lanes to HOV lanes, hours of operation, signing and pavement markings, enforcement practices and provisions, energy and air quality impacts, evaluation, and research.

TABLE 4 Major issues and concerns

Topic	Issues/Concerns	
	Freeway and Separate Right-of-Way	Arterial Street
• HOV policy considerations	14	8
• Planning	15	6
• Public involvement	12	6
• Demand estimation	16	7
• Funding/financing	13	5
• Design	15	5
• Converting general-purpose lanes to HOV lanes	19	8
• Congestion pricing on HOV lanes	17	6
• Managing demand-vehicle occupancy levels	15	5
• Hours of operation	13	6
• Marketing	14	5
• Operations	11	4
• Incident management	10	3
• Signing and pavement markings	11	7
• Enforcement practices and provisions	20	8
• Support facilities (park-and-ride lots, transit centers, etc.)	12	5
• Transit services	14	5
• TDM	10	4
• ITS	11	4
• Energy and air quality impacts	13	7
• Other environmental impacts	9	5
• Evaluation	13	6
• Research	9	6

A wide range of issues and concerns were identified by survey respondents in the open ended question. Table 5 identifies the general nature of the issues noted most frequently. Enforcement, low utilization levels, converting general purpose lanes to HOV lanes, and funding were noted by at least six respondents. A complete listing of the survey comments is provided in Appendix D.

Respondents were also asked to identify any actions in their area that may positively or negatively affect the viability and desirability of HOV systems. As shown in Table 6, a mix of positive and negative factors were noted by the respondents. Positive factors included major corridor or facility studies, good coordination and cooperation among agencies, and regional transportation plans with significant

TABLE 5 Top issues and concerns identified by respondents

Issue	Number
Enforcement problems/lack of enforcement	12
Converting general purpose lanes to HOV lanes	8
2+ vs. 3+ occupancy requirements/managing demand	8
Concern over low utilization levels	7
Funding	7
Opposition to HOV facilities/lack of political and public acceptance	6
Safety issues	6
Marketing	2

TABLE 6 Actions affecting the viability and desirability of HOV systems

Positive Actions[1]	Negative Actions
• Corridor or facility studies underway that include consideration of HOV alternatives. (8)	• Lack of funding. (5)
• Good coordination and cooperation among agencies. (4)	• Enforcement problems. (3)
• Regional transportation plans include significant HOV component. (4)	• Lack of political support. (2)
• New local tax supporting transit approved.	• Lack of public acceptance, especially by drivers in general-purpose lanes. (2)
• Increasing congestion in area.	• State departments of transportation not interested in HOV.
• Joint marking program underway.	• Local transit agency not interested in HOV.
• Business and private sector involved in promoting ridesharing, transit, and other strategies.	• Lack of coordination among agencies.
• Phasing construction contracts to ensure operable HOV segments.	• Environmentalists do not support HOV facilities.
• Local congestion pricing study.	• Air quality questions related to HOV facilities.
• Changes in state law allowing HOV toll proposals.	• No plan at state level.
• Toll/HOV demonstration project built and operated by private sector	• LRT is emphasis in area.
	• Action to reduce employer rideshare programs.
	• Planning to allow SOV use of HOV lanes during off-peak.
	• Legislation proposed to allow alternative fuel vehicles to use HOV lanes.

[1] Number of responses indicating same general concern is shown in the parenthesis.

TABLE 7 Other items to be addressed in the *HOV Systems Manual*

• Economic evaluation of HOV including time and cost of assembling HOV riders.
• Planning consistency with area transportation networks and analysis of land use impacts.
• Political impact on HOV system decision making and operations.
• Key elements to include in HOV feasibility analysis.
• Interagency partnerships to implement HOV systems.
• Identifying congestion levels which require HOV systems.
• Comprehensive approach to speeding buses through congestion.
• How park-and-ride facilities can be served by bicycles and walking to reduce pollution.
• Elements to be included in analyzing alternative types of HOV facilities.
• Use of HOV facilities in incident management and inclement weather.
• Signing needs for changes in vehicle occupancy requirements on a facility.
• How is enforcement funded? What are options and experiences?
• HOV treatments on urban interstate with constrained widths and on circumferential highways.

TABLE 8 Participation in development of *HOV Systems Manual*

Activity	Number
Review draft outline	20
Review specific chapters	20
Review implementation plan	17
Participate in telephone conference calls	11
Participate in video conference	5
Participate in training session or other implementation activities	14
Communicate by on-time techniques such as e-mail	9

HOV components. The most frequently noted negative factors focused on inadequate funding levels, lack of political support and public acceptance, and enforcement concerns.

HOV Systems Manual Elements

Information was also obtained on additional elements to be included in the *HOV Systems Manual*. The elements identified by the survey respondents are highlighted in Table 7. This information was used to help identify gaps and weaknesses in current practice and was incorporated into the detailed outline for the HOV manual.

Involvement in Development of the HOV Systems Manual

Survey respondents were asked if they would like to participate in the development of the *HOV Systems Manual*. Seven options for participation were noted. These ranged from reviewing the draft outline and draft chapters, to participating in conference calls, video conferences, and training sessions. As noted in Table 8, many individuals indicated an interest in assisting with the development of the *HOV Systems Manual*. The most interest was shown in reviewing the draft outline, chapters, and implementation plan.

CHAPTER 3

INTERPRETATION, APPRAISAL, APPLICATIONS

INTRODUCTION

This chapter presents a more detailed analysis of the gaps and weaknesses in current practice and knowledge relating to the various aspects of HOV facilities identified in the first phase of the project. The results from the literature review and the practitioner survey were used to help identify unresolved issues associated with HOV systems. The HOV research program, developed by the TRB HOV Systems Committee and input from other groups, was also used in this effort. The gaps and weaknesses in current practice and knowledge are presented according to the same 10 general categories used in the literature review.

HOV Facility Policy Considerations

The survey results indicate that many state DOTs, transit agencies, MPOs, and other agencies have formal policies or informal practices related to HOV facilities on freeways and in separate rights-of-way. Fourteen respondents reported formal HOV policies, while 11 indicated the existence of informal practices. Fewer agencies appear to have formal or informal polices addressing arterial street HOV facilities. Only four respondents reported formal policies for arterial HOV applications, while seven noted informal practices.

The literature review identified examples of state DOT policies related to HOV facilities. These vary in scope and in level of detail, however. Although the survey results and the literature review indicate that many agencies have policies to help guide planning, designing, and operating HOV projects, policy considerations were still identified as a major issue or concern by almost half of the survey respondents. The following represent some of the major gaps and weaknesses relating to HOV policy considerations.

- Coordinating policies of various agencies at the local, state, and federal levels;
- Coordinating policies among different metropolitan areas;
- Lack of specific policies and guidelines relating to
  - vehicle-occupancy levels,
  - changing vehicle occupancy to manage demand,
  - congestion pricing on HOV lanes,
  - innovative funding strategies, and
  - arterial street applications and systemwide planning;
- Building public support for HOV facilities;
- Building political support for HOV facilities;
- Identification of supporting policies to enhance HOV operations and strategies to promote their adoption and use by appropriate agencies;
- Coordinating parking policies with HOV policies;
- Converting a general-purpose lane to an HOV lane;
- Building support for HOV facilities among environmental groups; and
- Approaches for implementing HOV lanes involving multiple jurisdictions.

HOV Facility Planning

The various planning guidelines and documents currently available appear to be adequately used by practitioners. The survey responses indicate that the AASHTO guidelines, the Parsons Brinckerhoff manual, the Caltrans and TxDOT manuals, and other local documents are used to guide HOV planning. The results of the literature review and survey suggest that while these guides adequately address most of the basic planning elements, some important topics are not currently covered. The following gaps and weaknesses related to HOV facility planning have been identified.

- Enhanced HOV demand estimation techniques for both short-range and long-range use of HOV facilities. The current FHWA-sponsored research project may address this need but further analysis may be sought because this issue was noted as an important one by survey respondents.
- Planning techniques for arterial street HOV applications.
- Planning techniques for converting a general-purpose lane to an HOV lane.
- Planning techniques for estimating air quality and environmental impacts of HOV facilities.
- Planning techniques for analyzing congestion pricing alternatives on HOV facilities.
- Planning techniques to estimate the impacts and changes in vehicle-occupancy requirements.
- Planning techniques for estimating new HOV users.

- Planning techniques for developing regionwide HOV systems.
- Planning techniques for identifying the maximum capacity of an HOV facility.
- Planning techniques for enhancing the interaction of HOV and rail facilities in the same corridor.

HOV Facility Design

Approximately one-half of the survey respondents reported the use of formal design guidelines for HOV facilities on freeways and in separate rights-of-way, while six individuals noted the use of informal design practices. Although only eight respondents reported formal arterial street design guidelines, this was still the highest response on the arterial question. Although these responses indicate that the current design guidelines are adequately used, a number of design issues and concerns were raised by practitioners. The following areas for improvements and additions were noted by respondents and identified as gaps through the literature review.

- Identification of preferred or desirable design standards for all types of HOV facilities,
- Identification of reduced design standards for all types of HOV facilities when the preferred standards cannot be met,
- Identification of safety impacts of various design features,
- Identification of enforcement design needs and treatments,
- Identification of design considerations related to part-time versus full-time HOV lanes,
- Identification of design considerations related to converting a general-purpose lane to an HOV lane,
- Identification of alternative approaches for phasing HOV facility designs, and
- Standardizing HOV facility signing and pavement markings.

HOV Facility Marketing

Informal marketing practices were reported by 15 practitioners, while five noted the use of formal marking guidelines. The *HOV Lane Marketing Manual* (*36*) developed for FHWA appears to have wide distribution and use. Marketing issues were still noted by 13 respondents, however, with most concerns relating to building public acceptance for HOV facilities. The following areas were identified through the literature review and the practitioner survey for further attention.

- Identification of techniques to build public acceptance for HOV facilities;
- Identification of techniques to build political acceptance for HOV facilities;
- Identification of funding for marketing programs—identification of available programs and the use of innovative approaches;
- Identification of marketing techniques and approaches for converting a general-purpose lane to an HOV lane;
- Identification of marketing techniques for changing vehicle-occupancy requirements to meet increasing demand facilities;
- Identification of marketing techniques for facilities with various occupancy requirements by time of day or lane segment;
- Identification of marketing techniques for visitors, tourists, and part-time HOV lane users; and
- Identification of marketing the benefits of HOV lanes to non-users.

HOV Facility Operations

Ten respondents indicated the use of formal guidelines for operating HOV facilities on freeways or in separate rights-of-way in their areas, while nine reported informal practices. Available documents cover most aspects associated with HOV operations, although some topics may be discussed only briefly. The following gaps and weaknesses related to HOV facility operations were identified by the survey respondents and through the literature review.

- Analysis of safety impacts of various types of HOV facilities and design treatments;
- Identification of techniques to manage demand on HOV facilities and how to increase vehicle-occupancy levels when needed;
- Development of incident management strategies—both on HOV facilities and by using HOV lanes to help manage incidents on the adjacent freeway or street;
- Identification of approaches for integrating HOV facilities with advance traffic management systems (ATMS) and other ITS technology;
- Identification of techniques for linking freeway and arterial street HOV operations;
- Identification of the operational issues associated with converting a general-purpose lane to an HOV lane;
- Analysis of alternative hours of operation;
- Identification of approaches to address the empty lane syndrome; and
- Identification of the experience with congestion pricing projects on HOV facilities and the operational issues associated with these programs.

HOV Facility Enforcement

Enforcement issues are addressed in the currently available HOV manuals. The use of formal enforcement guidelines on freeway HOV lanes and those in separate rights-of-way were

reported by 16 of the survey respondents, while nine noted informal practices. Issues related to enforcement practices and provisions were the most frequently noted concerns by survey respondents. The following enforcement gaps and weaknesses were identified in phase one of this research study.

- Analysis of the use of advanced technologies to enhance HOV facility enforcement and identification of appropriate applications;
- Identification of approaches to build good working relationships among law enforcement agencies and the court system to help ensure HOV lane violations will be pursued;
- Identification of alternatives for funding enforcement programs, including assessing federal programs available to support enforcement and innovative funding approaches;
- Identification of approaches to deal with frequent HOV lane abuse;
- Analyzing the effectiveness of self-enforcement programs like the HERO program;
- Analyzing approaches to remote enforcement and ticket-by-mail programs; and
- Identification of innovative enforcement techniques;

HOV Facility Implementation

Factors associated with implementing HOV facilities are not adequately addressed in most of the current guidelines and manuals. A number of the issues raised by practitioners in the survey related to implementing different types of HOV facilities. The following gaps and weaknesses in current practice and knowledge were identified by the survey respondents and through the literature review.

- Identification of techniques to enhance agency coordination during implementation,
- Identification of techniques to phase HOV lane implementation so that meaningful segments are opened,
- Identification of techniques to prevent the empty lane syndrome during the initial phases of a project,
- Identification of techniques to manage traffic during construction,
- Identification of innovative contracting techniques, and
- Identification of techniques to implement general-purpose lane conversions.

Support Facilities, Services, Policies, and Programs

As discussed in the literature review, a number of guidelines and reports address various support facilities, services, policies, and programs. Park-and-ride lots and transit services are the most frequently discussed supporting services. For example, design guidelines for park-and-ride lots are included in existing HOV and park-and-ride facility manuals. Eleven of the practitioners responding to the survey reported the use of formal guidelines for supporting components, while 14 indicated informal practices. Fewer respondents identified the use of formal guidelines or informal practices related to transit services and travel demand management (TDM) programs. The following gaps and weaknesses associated with supporting elements were identified from the literature review and surveys.

- Developing enhanced techniques to locate and size park-and-ride lots;
- Analyzing techniques for comparing rail transit with HOV facilities;
- Identification of approaches to maximize the interaction between rail and HOV facilities in the same corridor;
- Identification of funding alternatives for transit and TDM including the use of federal, state, and local sources and innovative funding techniques;
- Identification of innovative techniques to encourage greater use of buses, carpools, and vanpools;
- Developing innovative transit services;
- Documenting the experience with different TDM programs to help identify the most effective strategies;
- Identification of techniques and approaches for obtaining support from local jurisdictions; and
- Identification of techniques and approaches for encouraging private sector support of HOV use by employees.

Environmental and Air Quality Impacts

The literature review and the survey results indicate that a consensus does not exist concerning the air quality and environmental impacts associated with HOV facilities. Many environmental groups argue that HOV facilities have a negative impact on air quality and vehicle emission levels. Other analyses indicate positive air quality affects. A comprehensive assessment of these issues is needed to address these concerns. Furthermore, adequate techniques are lacking to assist transportation professionals in analyzing the effects of HOV projects on air quality levels. The current studies being sponsored by the FHWA, EPA, and other groups may help address the need for better modeling techniques. The following gaps and weaknesses related to air quality and environmental impacts of HOV facilities have been identified.

- Assessing the impact of HOV lanes on air quality, vehicle emissions, and other environmental elements;
- Developing better techniques for estimating the air quality, energy, and environmental impacts of HOV facilities;
- Assessing the impact of HOV lanes on land use and urban sprawl; and

- Identification of techniques and methods for building support for HOV facilities among environmental groups.

HOV Facility Evaluations and Research Needs

Many of the gaps and weaknesses discussed in the previous sections represent ongoing research needs. The lack of continuing evaluations of HOV facilities has restricted the ability to adequately respond to many of the issues raised regarding HOV facilities. The *Program of Research for HOV Systems* (*57*), developed by the TRB HOV Systems Committee, provides additional direction on needed research studies.

A number of research needs were identified during the development of the *HOV Systems Manual.* These needs were used to develop a multifaceted HOV system research program. Problem statements were developed on the key research needs. These problem statements can be used to initiate a comprehensive ongoing HOV research program that is responsive to the needs of public agencies, policy makers, private consulting firms, and other groups. It builds on the efforts initiated by the TRB HOV Systems Committee. This Committee would be a logical group to finalize an updated research program and to help oversee the ongoing research studies.

Numerous opportunities exist to advance the research needs identified in the development of the *HOV Systems Manual.* Potential funding sources for these research projects include the FHWA, FTA, EPA, NCHRP, TCRP, national organizations, state DOTs, transit agencies, MPOs, consultants, and other groups.

The TRB HOV Committee or other groups could expand these preliminary research needs into more detailed problem statements for consideration by potential funding sources. The Committee could also provide ongoing assistance to monitor the status of research projects, help transfer study results into practice, and update the research agenda to reflect current needs and issues.

The research needs identified for each topic area are not presented in any type of priority order. Nor have priorities been established across topic areas. These steps could be undertaken by the TRB HOV Systems Committee or other groups.

Two multifaceted research problem statements focusing on priority pricing with HOV lanes and converting a general-purpose lane to an HOV lane are suggested. These research projects, which are highlighted below, consolidate the issues identified during the development of the Manual. Both of these topics are currently of significant interest to a wide range of groups and consolidating them into two comprehensive studies represents a logical approach.

Planning, Implementing, Operating, and Evaluating Priority Pricing Projects. Priority pricing, high-occupancy toll (HOT) lanes, and other related approaches are being considered and implemented with HOV facilities in some areas. Given the limited experience with these types of projects, additional research related to policies, planning, designing, implementing, marketing, operating, enforcing, and evaluating these types of projects is needed. This project proposal here would provide a comprehensive research study on all these issues. Planning elements would include an assessment of demand estimation techniques, pricing elasticities, and factors that may influence public and political acceptance. Issues to be examined include electronic and manual operational approaches, special design and operational needs, enforcement techniques, and public information and marketing. The study would examine the experience with existing projects and would develop a national database. Updated information on all these topic areas could be incorporated into future updates of the *HOV Systems Manual.*

Planning, Implementing, Operating, and Evaluating the Conversion of a General-Purpose Lane to an HOV Lane. A second multifaceted research project is suggested focusing on converting a general-purpose lane to an HOV lane. The experience to date with this approach is both limited and mixed. This study would examine the range of potential issues with lane conversion projects. Topics to be addressed include planning and demand estimation techniques, the conditions and factors which appear necessary for public and political support, methods to estimate potential impacts on the remaining general-purpose lanes, enforcement issues, special design considerations, and effective public information and marketing techniques. The study would also provide a comprehensive assessment of past and current lane conversion projects and would develop a national database on these types of facilities. The results of the project could be incorporated into future updates of the *HOV Systems Manual.*

Policy Considerations with HOV Facilities

Additional research is needed on a number of topics related to policy considerations with HOV facilities. The following research statements provide an indication of the major areas for further research to assess the impact of various policies, to explore techniques to enhance coordination among policies at different governmental levels, and to explore techniques to build support for HOV facilities.

Assess the Effectiveness of Policies Relating to HOV Facilities. As identified in the Manual, states, MPOs, and cities are adopting policies relating to HOV facilities. While examples of these policies were examined during the development of the Manual, additional research is needed to evaluate the effectiveness of different goals, policies, and objectives. This research study would provide a comprehensive

inventory of HOV policy directives currently in use at the federal, state, regional, and local levels. The effectiveness of various policies and approaches would also be examined. Guidelines would be outlined on the development and implementation of effective HOV policies for all levels of government. The study would also identify techniques to encourage the adoption and use of these policies by the appropriate agencies and groups. Policies related to the following elements and other issues would be examined: vehicle-occupancy levels, changing vehicle occupancy to manage demand, congestion pricing on HOV lanes, innovative funding strategies, arterial street applications, and systemwide planning

Assess Techniques to Enhance the Coordination of Policies Relating to HOV Facilities and Supporting Components. In many metropolitan areas, policies related to various aspects of the transportation system are not coordinated. For example, parking policies may encourage commuters to drive alone through the provision of convenient and inexpensive parking. Research is needed to examine the relationships among policies associated with parking, transit fares and services, HOV facilities, TDM strategies, and other elements of the transportation system. The research would help identify those policies, and the packaging of coordinated policies, that best maximize the use of all HOV modes.

Assess Coordination of HOV-Related Policies Among Different Metropolitan Areas. As identified in the Manual, the extent, nature, and scope of policies related to HOV facilities and other supporting elements varies widely by state and by metropolitan area. Research is needed to determine the potential for greater coordination among states and metropolitan areas and the benefits of enhanced coordination. This research project would explore the advantages and disadvantages of coordinating HOV-related policies among different areas, the feasibility of improving coordination, and approaches to facilitate enhancing coordination.

Planning HOV Facilities

The development of the *HOV Systems Manual* identified a number of areas where additional research is needed to advance the state-of-the-practice related to planning HOV facilities. As addressed below, additional research on estimating the demand for various types of HOV facilities, forecasting the environmental impacts of HOV projects, and developing planning techniques for special conditions, such as priority pricing and converting a general-purpose lane, are especially critical.

Enhanced HOV Demand Estimation Techniques. Although the previously noted FHWA-sponsored study developed a sketch planning tool for estimating the potential demand for an HOV facility, additional research is still needed in this area. This research should focus on developing enhanced techniques for forecasting both short-range and long-range use of HOV facilities. This research should include assessing the techniques for estimating new HOV users for various types of facilities, as well as the demand at different vehicle-occupancy levels.

Planning and Demand Estimation Techniques for Arterial Street HOV Applications. As identified in the Manual, most of the available planning and demand forecasting methodologies focus on HOV facilities on freeways and in separate rights-of-way. Few approaches and techniques are available for practitioners interested in planning arterial street projects. Research should be conducted on the methods that are being used to plan bus-only lanes, HOV lanes, and bus and HOV signal priority projects in the arterial street environment. The development of a comprehensive planning guide for these types of facilities, which would update the current chapter in this Manual, should be the desired outcome of the study.

Assessing the Impact of HOV Improvements on Air Quality and the Environment. The research conducted for the Manual points out the lack of good information on the air quality impacts of HOV facilities. In general, the impacts of HOV lanes on air quality are more complex and less well understood than generally thought. Research is needed to quantify the vehicle occupancy and congestion tradeoffs involved in HOV lane implementation, and model the impacts of HOV lanes on air quality and other environmental considerations. Issues to be examined include how to model HOV networks to estimate air quality, the impact of HOV lanes on traffic operations and air quality, the effects of lane conversions compared to adding an HOV lane, and the impact of HOV facilities on noise, water quality, and other issues.

Planning Techniques to Estimate the Impacts of Changing Vehicle-Occupancy Requirements. As identified in the development of the Manual, little documentation exists on the impacts of changing vehicle-occupancy levels on HOV facilities, especially with increasing occupancy requirements. Additional research is needed to assess the impacts of both increasing and decreasing vehicle-occupancy requirements. This study should include an analysis of changes in carpool and bus use, impacts on general-purpose lane traffic, enforcement issues, and other factors. The research should also develop techniques for better estimating changes in HOV demand and other impacts from increasing or decreasing vehicle-occupancy requirements.

Planning Techniques for Developing Regional HOV Systems. Examples of regional HOV system plans, and the procedures used to develop these plans, were examined during

the development of the Manual. A variety of approaches and analysis methods are currently being applied to conduct regionwide HOV planning. Additional research is needed to explore these techniques in more detail, to assess the advantages and limitations of the various approaches, and to develop enhanced techniques for planning regional HOV systems and for incorporating HOV facilities into existing regional long-range transportation plans. The research should also examine techniques to ensure greater coordination, cooperation, and communication among the various governmental levels and agencies responsible for planning, operating, and enforcing the various elements of the surface transportation system, including all types of HOV facilities. Guidelines on methods to foster improved coordination should be identified.

Planning Techniques for Enhancing the Interaction of HOV and Rail Facilities in the Same Corridor. Additional research is needed to examine the interaction and coordination among HOV lanes and rail transit systems operating in the same corridor. Differences of opinion currently exist on whether these services can be complimentary and serve different markets, or whether they are in competition and serve the same markets. Research is needed to assess the markets served by these modes, to identify techniques that can be used to enhance coordination among HOV facilities and rail services, and to explore other potential issues that may emerge in planning both types of facilities in the same corridor.

Assessing the Maximum Capacity of an HOV Facility. One of the issues that often emerges during the planning process for an HOV facility is determining the maximum capacity of an HOV lane. This issue is especially important when HOV lanes are considered with or are being compared to other types of improvements, including rail transit alternatives. Further research should explore the capacity of various types of HOV facilities using different vehicle-occupancy and vehicle-eligibility requirements.

Assessing the Influence of HOV Facilities on Land Use and Development Patterns. Little information exists on the impact various types of HOV facilities have on land use patterns in an urban area. There have been some suggestions that HOV lanes may contribute to urban sprawl, by allowing people to live longer distances from their place of work while maintaining similar travel times by carpooling, vanpooling, or taking the bus. Additional research is needed to better understand the complex dynamics influencing land use and development patterns, and the possible influence HOV facilities may have on these trends.

Planning Techniques for Special Use Lanes. Little information is available on allowing trucks or other special user groups to access HOV lanes. Additional research is needed to explore the potential issues and opportunities associated with opening HOV lanes to trucks and additional user groups. The research should also examine the advantages and disadvantages of different approaches, develop planning guidelines for use in considering multiple user groups, and identify other factors that should be considered in the planning process.

Operation and Enforcement of HOV Facilities on Freeways and in Separate Rights-of-Way

The results from the literature review and the survey of practitioners, along with the development of the final manual, identified numerous research needs related to operating and enforcing HOV facilities on freeways and in separate rights-of-way. These research needs focus on ways to enhance the operation and enforcement of HOV lanes, as well as examine a variety of issues associated with the use of different types of facilities.

Assessment of Effective HOV Enforcement Procedures. Effective enforcement is critical to the success of an HOV facility. The variety of HOV lane designs and operating scenarios present an increasing range of enforcement options and problems. At the same time, police agencies are facing funding cutbacks which limit the personnel available for assignment to HOV enforcement. To maximize available personnel, more efficient and effective enforcement approaches must be developed, evaluated, and implemented. This study would examine the design and placement of enforcement areas, the use of automated enforcement techniques and ticket-by-mail programs, impacts of design features on violation rates and enforcement requirements, the deterrent effects of publicized penalties, the role and effectiveness of HERO programs, and other related efforts. The project would identify deployment levels, enforcement techniques, and design features that maximize compliance with HOV regulations. It would also develop HOV enforcement guidelines for police and other agencies. The study would explore and identify approaches to building strong working relationships between enforcement agencies and the court systems to help ensure that HOV lane violations will be upheld. Funding alternatives for enforcement programs would also be examined.

Experience with HOV Eligibility and Operational Definitions. The vehicle-occupancy requirements, vehicle-eligibility regulations, and hours of operation currently in use with HOV facilities were all discussed in the Manual. Decisions on these factors and other elements will influence the operation of an HOV lane and public perception. It may also be necessary to reassess these requirements in response to too high a demand, as well as under-utilization of a facility. Additional research is needed to assess the full range of approaches for managing demand on HOV facilities and

the operational steps required to implement these techniques. Strategies to be considered include changing vehicle-occupancy requirements, variable time-of-day restrictions, allowing lower occupancy or single-occupancy vehicles (SOV) to use the lane for a fee, and other options. This study would examine these issues and document the experience with HOV facilities that have used different techniques to manage demand. The results of this analysis would be used to develop guidelines for managers and operators faced with the problem of HOV lanes which are either too crowded or too empty.

Analysis of Mode Choice on Existing HOV Facilities. Several studies have documented the increase in HOV usage on affected freeways immediately following the implementation of an HOV facility. Less research is available, however, on the formation of new carpools in response to a new HOV lane, or on existing carpools that change their routes to take advantage of the time savings offered by the lanes. Few studies have tracked the growth of carpool formation over time as an HOV lane matures or documented the impact of HOV facilities on parallel transit lines. Improving the ability to assess the short- and long-term impact of HOV lanes on carpooling and transit ridership would benefit planners and would assist in developing and calibrating mode-choice models. This study would analyze existing data on the growth of carpooling and transit use in HOV lanes over time. It would attempt to isolate the impact of the HOV lanes on mode choice alternatives.

Comparison of Actual and Perceived Travel Time Savings and Travel Time Reliability for HOVs. Studies have indicated that people using HOV facilities often wrongly estimate their travel times and travel time reliability. HOV lane users tend to overestimate the time savings from using a facility, while non-users tend to underestimate the potential savings. In addition, HOV lane users and non-users may have different perceptions of the travel time reliability of HOV facilities. Since research has shown that people make transportation decisions based on their perceived travel times as well as travel time reliability, it is important that this issue be examined. This research would assess the perception of travel time savings and travel time reliability by HOV lane users and non-users, the elements that affect these perceptions, and techniques to communicate more accurate information on travel times and travel time reliability to users and potential users of HOV facilities.

Developing HOV Systems to Improve Efficiency. The information examined in this Manual indicates that HOV lanes are more effective when applied in conjunction with a variety of complementary treatments, such as queue-jump treatments at freeway entrance ramps, park-and-ride lots, and transit centers. A full understanding does not exist, however, of what techniques and approaches have the most influence on encouraging greater use of HOV modes. This research would examine the strategies used by various agencies in developing a variety of HOV facilities and HOV networks. It would also develop approaches to integrating all aspects of the highway-based transportation system, including bus transit and bus-to-rail connections, with HOV networks.

Assessment of Incident Management Strategies. A variety of techniques are currently being used to respond to incidents and accidents on HOV facilities. In addition, different policies and approaches are in use to govern opening HOV facilities to help manage incidents on the adjacent freeway or street. Additional research is needed to better document the current practices and to develop alternative approaches for enhancing incident response capabilities on HOV facilities, as well as the use of HOV lanes to manage incidents on adjacent facilities.

Assessment of ITS to Enhance the Operation of HOV Facilities. The application of ITS with HOV facilities was discussed in the Manual. In most areas, ITS applications are still in the testing and initial deployment phases. As a result, experience is still being gained on the use and benefits of various ITS and other advanced technologies with HOV facilities. Additional research is needed to document and analyze current projects, and to further explore innovative techniques and applications.

Assessment of Techniques to Link Freeway and Arterial Street HOV Operations. Few examples exist of regional HOV networks that include linking facilities on freeways or in separate rights-of-way with those on arterial streets. Since congestion levels on arterial streets often contribute significantly to the travel time delays experienced by carpools, vanpools, and buses, enhancing the connection between HOV facilities on all types of freeways and roadways may have significant benefits. This research would examine existing examples of links between freeway and arterial street HOV facilities and would identify techniques and approaches that could be used to encourage additional connections.

Enhancing HOV Simulation Models. Currently, many HOV operational considerations cannot be modeled. Improvements in existing simulation models and new models are needed to better assess HOV lane alternatives and operational strategies. This project should examine improved simulation models for assessing HOV lane alternatives, as well as access options, and when and where to terminate an HOV facility. The results of this study would provide practitioners with enhanced models for simulating various HOV lane, access, and end treatments.

Design of HOV Facilities on Freeways and in Separate Rights-of-Way

Many agencies use formal design guidelines for HOV facilities on freeways and in separate rights-of-way, while other agencies use informal design practices. A number of design issues and concerns were identified by individuals responding to the survey and during the development of the Manual. Areas for additional research related to HOV facilities on freeways and in separate rights-of-way are discussed in this section.

Assessment of Design Treatments for HOV Facility Access, On-Line Stations, and End Treatments. The design of ingress and egress points and end treatments associated with HOV lanes plays a significant role in the effectiveness of these facilities. The increased use of HOV lanes by buses and the development of multimodal links in urban transportation systems are also creating the need to explore on-line HOV station designs for mixed-vehicle use. A variety of ingress, egress, end treatments, and on-line station design applications for HOV facilities are currently in operation throughout North America. This research would examine the issues associated with the safety and effectiveness of different design applications and would develop more detailed guidelines on the design of these facilities.

Assessment of Safety Aspects of Various HOV Lane Designs. A variety of design treatments are used with HOV facilities on freeways and in separate rights-of-way. These may include variations in the separation from the general-purpose travel lanes, the presence or absence of median shoulders adjacent to HOV lanes, and other features that may affect the safety of the HOV and the general-purpose lane operation. Before-and-after comparisons, along with assessments of control freeways, are needed to document the impact of different design treatments on accidents and safety. This research study would examine the impact of various design treatments on safety issues, and would identify techniques to address specific concerns.

Assessment of Enforcement Design Treatments. The important role that enforcement plays in successful HOV projects was stressed throughout the Manual. A variety of enforcement areas, strategies, and design treatments are currently in use with HOV facilities throughout North America. Additional research is needed to examine the design issues associated with alternative enforcement approaches. This study would examine alternative designs for enforcement areas and other enforcement treatments, including design issues associated with the use of advanced technologies and remote enforcement. It would develop more detailed guidelines on designing various types of HOV enforcement approaches.

Assessment of Design Considerations for Part-Time Versus Full-Time HOV Facilities. Some HOV lanes are used only during the morning and afternoon peak periods, while others are in operation during only one of the peak periods. These facilities revert to shoulders, general-purpose lanes, or other functions during the remainder of the day. Other facilities operate as HOV lanes on a 24-hour basis. Further research is needed on the design issues associated with part-time HOV facilities. This study would examine both reduced and full design standards, the issues associated with the use of different designs, and case study examples of various approaches. The study would develop more detailed guidelines on designing part-time HOV facilities that could be incorporated into future updates of the Manual.

Assessment of Standardizing HOV Facility Signing and Pavement Markings. The use of different signing and pavement markings with HOV facilities in North America was discussed in the Manual. Additional research is needed to explore the potential to standardize these elements among various areas and states. This study would explore the issues associated with implementing a uniform approach. It would suggest a common set of signs and markings and would outline possible implementation techniques.

Operation and Enforcement of Arterial Street HOV Facilities

The research conducted in this project reinforces the lack of available information on operating and enforcing arterial street HOV facilities. The characteristics of the arterial street environment are different from those on freeways or in separate rights-of-way. As a result, much of the experience gained over the years in operating and enforcing HOV facilities on freeways and in separate rights-of-way is not directly transferrable to arterial street projects. A comprehensive research program, which includes the following projects, is needed to address the operation and enforcement of HOV facilities on arterial streets.

Assessment of Operating Arterial Street HOV Treatments. Additional research is needed to fully explore the operation of existing arterial street HOV lanes. This study would start with a comprehensive documentation of the current use of different treatments. It would also explore utilization rates for buses, as well as carpools and vanpools. Potential issues associated with different techniques would be highlighted, along with approaches for addressing these issues. Operational concerns and strategies appropriate with bus-only lanes, HOV lanes, bicycle and HOV lanes, and other unique situations would be explored. Although many of these issues were examined briefly in the development of the *HOV Systems Manual*, a detailed assessment was outside the scope of this research. Additional studies are needed to

explore the operation of existing and planned arterial street applications.

Priority Treatments for HOVs at Signalized Intersections. Much of the delay experienced by HOVs on arterial streets is caused by traffic signals at intersections. More research is needed to fully document the current practices to give HOVs priority at signalized intersections. This project would also examine the issues associated with providing priority through different techniques and the potential use of ITS and other advanced technologies to overcome these concerns.

Enforcement of Arterial Street HOV Treatments. Enforcing HOV facilities on arterial streets is different from policing facilities on freeways and in separate rights-of-way. Additional research is needed to assess the use of different enforcement strategies and techniques, to identify those that appear to be most effective, and to examine new approaches using ITS and other advanced technologies.

Development of Evaluation Procedures and Data-Collection Techniques for Arterial Street HOV Treatments. As noted previously, suggested procedures for monitoring and evaluating freeway HOV facilities were developed as part of a multiyear FTA-funded research project. Similar procedures have not been developed for arterial street HOV facilities. This research would start with a review of before-and-after studies, evaluation programs, and data collection techniques with the different types of arterial street HOV facilities. The results of this assessment would be used to develop suggested objectives, measures of effectiveness, data collection techniques, and comprehensive ongoing monitoring and evaluation programs for use with different priority measures for HOVs on arterial streets.

Coordinating Land Use and Arterial Street HOV Facilities. Arterial street HOV facilities may impact adjacent land uses in a number of ways. These include limiting access at driveways or intersections, removing or restricting on-street parking and delivery vehicles, and other impacts. Additional research is needed to obtain a better understanding of the effects arterial street HOV lanes may have on land uses and developments, to identify techniques to overcome potential negative impacts, and to identify approaches to better integrate land use and site design planning with planning and operating arterial HOV facilities.

Design of Arterial Street HOV Facilities

The analysis conducted for this project points out the need for additional research on a variety of topics related to the design of arterial street HOV facilities. The following studies should be included in the comprehensive research program for arterial street HOV treatments described in the previous section. The results of these research projects should be incorporated into future updates of the *HOV Systems Manual*.

Assessment of Design Issues with Arterial Street HOV Facilities. More research is needed to examine the design issues associated with various types of arterial street HOV treatments. The detailed examination of these issues was outside the scope of this research study. Topics which should be explored in more detail include design treatments to accommodate turning vehicles at intersections and at driveways, issues associated with on-street parking and delivery vehicles, and accommodating bicyclists and other user groups. The results of this study would be a more comprehensive design guide for all types of arterial street HOV facilities.

Assessment of Safety and Enforcement Design Treatments with Arterial Street HOV Facilities. The design of an arterial street HOV facility may impact the safety of users and non-users, as well as the ability to enforce the lane. Additional research is needed to examine the safety and enforcement issues associated with different design treatments. This study would explore current design features of arterial street HOV projects, potential safety and enforcement concerns, and potential enhancements to address these concerns.

Assessment of Design Issues with Arterial Street Signal Priority Projects. As identified in the development of the *HOV Systems Manual*, providing priority for buses and other HOVs at signalized intersections is not widespread. A number of design and operating issues have limited the use of this approach in many areas. Additional research is needed on the design of signal priority projects. This research project will examine the design issues associated with the intersection, the signal timing and signal algorithms, and other issues commonly associated with this technique. The results of the study would provide more detailed guidelines for designing signal priority projects.

Assessment of Standardizing Arterial Street HOV Facility Signing and Pavement Markings. This research project, which would examine the potential to standardize signing and pavement markings for HOV facilities on arterial streets, could be coordinated with the freeway project discussed previously. A more detailed assessment would be made of currently used signs and pavement markings, and the potential to implement a uniform approach.

Transit Services and Facilities

The use of various types of HOV facilities by transit services was discussed in the *HOV Systems Manual*. The implementation of new or restructured express bus service is the most commonly found approach with HOV lanes. Although

the benefits HOV facilities offer public transit services have been documented in some areas, there is still a need to better understand the impacts different design treatments and operating scenarios have on bus services. For example, a consensus does not currently exist on the impact of carpools and vanpools on bus operations. The following research studies have been identified through the literature review, the survey of practitioners, and the TRB HOV Systems Committee to help maximize the benefits of HOV facilities to transit operations. The results of these studies could be incorporated into the ongoing updates of this Manual.

Assessment of Transit Operations and Innovative Transit Services with HOV Facilities. Although case study examples of bus services with HOV facilities were identified during the development of the Manual, a detailed assessment of the impact on transit operations was beyond the scope of this project. A more detailed examination of the use of HOV facilities by transit operators, the impact of various design and operating scenarios on bus services, the implementation of new and innovative transit services, and the advantages and disadvantages of different design and operating approaches is still needed. This study would examine the impact of busways, freeway HOV facilities, and arterial street HOV applications on transit operations and services. It would also document the use of new services, such as reverse-commute routes, timed transfer networks, crosstown routes, suburb-to-suburb routes, and buspools. The results of this study would provide guidelines for use in planning, implementing, and operating innovative transit services with HOV facilities and maximizing the benefits of HOV facilities to transit operators.

Assessment of Rail and HOV Coordination. A few examples were identified during the research of rail transit and HOV/bus operations in the same travel corridor. Additional research is needed to examine coordinating rail and HOV/bus operations in the same corridor, as well as coordinating services in different corridors in the same metropolitan area. This research study would document existing examples in more detail and would outline other techniques for enhancing intermodal and multimodal coordination.

Developing Improved Techniques for Estimating the Demand for Park-and-Ride Facilities. As discussed in this Manual, a number of techniques are currently available for estimating the demand for park-and-ride facilities, as well as locating and sizing these lots. These techniques have strengths and weaknesses. Additional research is needed to develop a better demand estimation model for different types of park-and-ride facilities. This research study would examine the existing techniques in more detail and would develop enhanced procedures for estimating the demand for park-and-ride lots associated with HOV facilities. It would also provide guidelines for locating and sizing these facilities.

Joint Development with HOV Facilities. A few examples of existing joint development projects with HOV facilities were identified in this research project. Joint developments are more frequently found with rail transit systems than with HOV and bus systems, however. This research would examine the current HOV joint development projects in more detail and would identify techniques that could be used to encourage more joint development activities with HOV facilities.

Supporting Programs and Policies

The important role that supporting programs and policies play in the success of an HOV facility was identified during the development of the Manual. The exact influence of many TDM strategies is still not well understood, however. Further research is needed to better document the impact that various TDM techniques can have and to identify those strategies that may have the greatest impact on increasing the use of HOV facilities. The following research studies would address these needs.

Analysis of Factors Impacting the Effectiveness of HOV and TDM Strategies. TDM techniques are being used in many areas to enhance the effectiveness of HOV facilities. More research is needed to better understand the influence of TDM strategies with HOV projects. This study would provide a comprehensive review of HOV and TDM applications, with emphasis on instances involving simultaneous application for which HOV user trip and purposes are known. The characteristics associated with the successful and unsuccessful implementation of these strategies would also be examined.

Assessment of Innovative Techniques to Encourage Greater Use of Carpools, Vanpools, and Buses. This study would provide a new perspective on techniques that could be used to encourage greater use of alternative travel modes and HOV facilities for both work and non-work trips. The experience with existing strategies would be documented, and potential new approaches would be identified and analyzed. The intent of the project would be to take a fresh look at the factors influencing mode choice and travel behavior and to match service strategies, the use of ITS technologies, and other techniques to meet these needs.

Implementing HOV Facilities

The development of the *HOV Systems Manual* identified a number of areas where additional research related to the implementation of HOV facilities is needed. These areas include exploring techniques to manage traffic during construction, to enhance agency coordination during implementation, and to

coordinate the opening of meaningful segments. Further research on innovative contracting techniques and special considerations for implementing general-purpose lane conversion projects and priority pricing projects is also needed.

Techniques to Manage Traffic During Construction. This research study would examine techniques to manage traffic during the construction of HOV facilities. The use of temporary HOV lanes to assist with the management of traffic during the reconstruction of existing freeways and roadways would also be addressed. Although examples of current approaches were highlighted in the Manual, further research is needed to explore other innovative techniques. The results of this research would document existing case studies and would present new approaches for use with future projects.

Techniques to Enhance Agency Coordination During Implementation. The implementation of an HOV lane and supporting facilities and services requires extensive coordination and cooperation among agencies. Although staff from these agencies will usually have established good working relationships during the planning and design phases, different personnel are often responsible for the implementation process. Additional research is needed to identify techniques that can be used to foster and promote greater coordination among agency personnel during the implementation phase. This research should explore approaches to ensure that the opening of facilities and the initiation of services are accomplished in a coordinated manner.

Implementation Phasing. Related to the previous topic, additional information is also needed on approaches to phase construction and implementation of HOV facilities. Experience indicates the importance of opening operable segments that provide significant travel time savings for HOVs. This research project would examine the approaches currently being used, present case studies, and outline enhanced techniques for phasing the implementation of HOV lanes, as well as supporting facilities and services.

Innovative Contracting Techniques with HOV Facilities. As highlighted in the Manual, many agencies are exploring and using innovative contracting techniques on a wide range of projects, including HOV facilities. Additional research is needed on the use of various techniques with HOV projects, the costs and benefits associated with these approaches, and the identification of other innovative strategies. The results of this study should include case study examples, guidelines for the use of different approaches, the benefits that can be anticipated from various mechanisms, and legal and policy issues that may need to be addressed with their use. The results, which could be incorporated into this Manual, would provide an easy-to-use guide for practitioners interested in using innovative contracting methods with HOV facilities.

Public Involvement and Marketing Program

The use of various public involvement and marketing techniques with HOV facilities is described in the *HOV Systems Manual*. In addition, the FHWA-sponsored *HOV Marketing Manual* provides more detailed information on marketing and promotional activities (*36*). Even with these two documents, however, there is a need for further research related to public involvement and marketing programs with HOV facilities.

Assessment of Techniques to Build Public and Political Acceptance for HOV Facilities. Additional research is needed to assess the techniques that are currently being used to build public and political acceptance with HOV facilities around the country and to identify new approaches. Although many public agencies have undertaken enhanced public education and outreach efforts, additional guidance on the most effective techniques is still needed. This research study would explore the approaches currently being used, as well as the techniques used by agencies and private sector groups on other projects. New approaches for gaining public and political support would also be identified. The study would develop guidelines on the various strategies that can be used, the advantages and limitations of different techniques, and approaches to consider based on specific conditions or situations.

Assessment of Information and Marketing Techniques for Visitors, Tourists, and Part-Time HOV Lane Users. Public information and marketing efforts related to HOV facilities are usually oriented toward commuters who use the lanes on a daily or regular basis. Less emphasis has been placed on promoting HOV lanes with part-time or periodic users, although HOV facilities are located in areas with significant numbers of visitors and tourists. This research study would examine the special information needs of visitors and tourists, the potential use of HOV facilities by these groups, and the techniques that could be used to promote HOV lane use. The study would identify approaches and strategies that could be implemented in different areas, the cost and benefits of various techniques, and methods to assess the impact of these programs.

Monitoring and Evaluating HOV Facilities

The *HOV Systems Manual* includes a comprehensive guide to developing policies, planning, designing, funding, implementing, marketing, operating, and enforcing HOV facilities. Regular updating of the Manual will be needed to ensure that it continues to reflect current practices and that

recent experiences with new projects and techniques are incorporated. The following research studies are needed to help maintain the Manual as a practical and useful guide.

Updating the *HOV Systems Manual*. The Manual should be updated on a regular basis to ensure that it reflects current trends and information. The research needs outlined in this chapter should be incorporated into these updates. The use of the three ring binder format allows for new or revised sections to be added easily.

Maintaining and Updating HOV Project Database. In addition to updating the *HOV Systems Manual*, the listing of current and planned projects, case study examples, and other information will need to be updated periodically. Maintaining a current database that provides accurate information on all projects would provide a resource for practitioners, policy makers, and others throughout the country.

Ongoing Monitoring and Evaluation of Studies. Support is needed for the ongoing monitoring and evaluation of HOV facilities throughout the country. Accurate and current information on the performance of HOV facilities is needed at the local, regional, state, and national levels. There is also a need for ongoing research studies at the local levels, as well as coordination of the studies at the national level.

CHAPTER 4

CONCLUSIONS AND SUGGESTED RESEARCH

This chapter is divided into two main sections. The major steps conducted during the development of the actual *HOV Systems Manual* are presented in the first section. The second section presents the proposed implementation plan for moving the manual quickly into practice. This plan has been updated and expanded from the approach given in the interim report. The *HOV Systems Manual*, the major product of the research project, is provided as a separate document.

DEVELOPMENT OF THE *HOV SYSTEMS MANUAL*

The interim report included a proposed format and a detailed outline for the *HOV Systems Manual*. The detailed outline included 13 chapters to provide a comprehensive approach for developing policies and for planning, designing, implementing, marketing, operating, enforcing, and evaluating HOV facilities. Furthermore, the use of a three-ring binder for the manual was recommended to allow for easy updating. Given the evolving nature of many aspects related to HOV facilities and ongoing research efforts, it is anticipated that there will be a need to update various sections of the Manual on a periodic basis.

The *HOV Systems Manual* was developed during the period from April 1996 to October 1997. A number of activities were conducted during this time to help ensure that the individual chapters contained up-to-date information on the status of projects and issues. Journal articles, papers, reports, conference presentations, and the Internet were all used to obtain current information for the Manual. In addition, e-mail and telephone calls to agency representatives, consultants, and other individuals were used as needed. Input was also received through conferences and other meetings. The following activities, which reflect those outlined in the plan for practitioner involvement contained in the Interim Report, were used to obtain input from transportation professionals during the development of the Manual.

NCHRP Panel Review and Input

The members of the NCHRP Panel were actively involved throughout the development of the *HOV Systems Manual*. The panel provided excellent suggestions and comments during both phases of the project. As noted previously, the NCHRP Panel members and the TRB and FHWA liaisons provided comments on the initial draft format and the detailed outline contained in the interim report. Comments and suggestions were incorporated into the revised interim report. The outline was used to guide the development of the various chapters.

The individual chapters of the draft *HOV Systems Manual* were mailed to panel members, the FHWA liaison, and the two TRB liaisons for review as they became available during Phase Two. The comments and suggestions from panel members were returned to the NCHRP staff and provided to the research team. The comments were reviewed by the research team and incorporated into the final draft of the Manual. This process greatly enhanced the development of the final draft *HOV Systems Manual*. Many excellent suggestions, corrections, and additional information on projects and facilities were provided by panel members. Responses to the comments identified how questioned points were addressed in the report. Copies of the responses were provided to the NCHRP panel members, the TRB and FHWA liaisons, and NCHRP staff along with the final draft *HOV Systems Manual*.

Practitioner Review and Assistance

A number of individuals volunteered to assist with the development of the *HOV Systems Manual*. Practitioners responding to the survey were able to indicate an interest in reviewing the outline and individual chapters. In addition, individuals at conferences and committee meetings also volunteered to provide updated information or to review various sections.

Many individuals with a wide range of experience helped with the development of the draft Manual (see Table 9). Assistance included reviewing the draft outline, providing updated information on projects, reviewing draft chapters, and reviewing the full draft. Telephone calls and e-mail were used extensively to obtain updated information. Although not all individuals who were sent drafts of various sections responded with comments, those who did provided valuable suggestions for enhancing the Manual. The major comments from these individuals and the corrections or additions made in the Manual were provided to the panel members with the final draft.

TABLE 9 Individuals providing assistance with the development of the *HOV Systems Manual*

Jerry Ayres, Washington State Department of Transportation
Dennis Dal Santo, Pace (Suburban Bus), Arlington Heights, IL
Mark Dierling, Minnesota Department of Transportation
Stefan Fabian-Marks, Intercity Transit in Thurston County, WA
Rob Fellows, WSDOT
George Human, City of Richardson, TX
Aaron Isaacs, Metropolitan Council Transit Operations, Minneapolis, MN
Bill Jeffrey, Virginia Department of Transportation
Ron Klusza, California Department of Transportation
Kevin Michel, Los Angeles County Metropolitan Transportation Authority
Robert Morgan, Minneapolis Public Works
Gary Nelson, Greater Cleveland Regional Transit Authority
Luisa Paiewonsky, Massachusetts Highway Department
Carl Quackenbush, Central Transportation Planning Staff
Mike Rainey, Metropolitan Transit Authority of Harris County (METRO)
Bruce Rizzieri, City of Albuquerque Transit and Parking
Burt Riddle, Georgia Department of Transportation
John Sedlak, Metropolitan Transit Authority of Harris County (METRO)
William Steffens, Massachusetts Bay Transportation Authority
David Schumacher, Metropolitan Transit Development Board

*Listed in alphabetical order.

Professional Organizations and Meetings

Input was also obtained from practitioners through committees and meetings of various professional organizations. Presentations were made by members of the research team during the development of the *HOV Systems Manual* at the 1996 TRB International HOV Systems Conference in Pittsburgh, as well as meetings of the TRB HOV Systems Committee, the ITE Transit Council, and the TRB TDM Committee. Two breakout sessions at the 1996 HOV Conference were devoted to a discussion of the detailed Manual outline and elements to be included. The extensive input received at these sessions were provided to the Panel members in September 1996 (see Appendix E). Feedback was also obtained on the Manual from participants at two pilot FHWA HOV training courses held in the summer of 1997. These included a 3-day pilot course in Washington, D.C. and a 1-day pilot course in Boston.

IMPLEMENTATION PLAN

This section outlines the proposed implementation plan for transferring the completed *HOV Systems Manual* into practice. The plan presents the approaches, methods, and techniques suggested to help ensure that the manual is quickly made available to practitioners and is incorporated into everyday use and practice. The proposed plan provides a coordinated and comprehensive technology transfer process necessary to advance the state-of-the-practice related to all aspects of HOV systems. The proposed implementation plan is comprised of the following eight elements. Additional resources will be needed to implement some of them.

- Marketing the *HOV Systems Manual;*
- Distributing the *HOV Systems Manual;*
- Using the *HOV Systems Manual* at national, state, and local training sessions;
- Maintaining the HOV Web Site;
- Publishing the *HOV Systems Manual* on CD-ROM;
- Using video to support the *HOV Systems Manual;*
- Distributing the Manual at national conferences; and
- Using the Manual in graduate and undergraduate courses.

These eight elements provide for broad coverage of different groups and audiences. These include transit and highway professionals, individuals responsible for air quality and congestion management activities, policy makers, special interest groups, undergraduate and graduate students, and others. The proposed implementation plan has been revised slightly from the draft plan included in the interim report. The potential for video conference training sessions has been incorporated into the general use of the Manual at training courses rather than highlighting this technique as a separate item. Marketing the Manual, publishing and distributing the Manual on a CD-ROM, and developing a video to support the Manual have been added as elements of the proposed implementation plan. The eight elements comprising the proposed implementation plan are summarized next.

Marketing the *HOV Systems Manual*

The NCHRP is responsible for the final production and distribution of the *HOV Systems Manual.* As part of this effort, a number of methods can be used to help market the Manual, and to inform transportation professionals, policy makers, and other groups of the availability of the Manual.

Possible techniques include the normal NCHRP notification methods, sending a postcard or flyer to the extensive TRB HOV Committee mailing list, posting information on the TRB HOV Committee Internet Web site, using publications of various organizations, and other techniques.

Distribution of the *HOV Systems Manual*

The NCHRP is responsible for distribution of the final *HOV Systems Manual*; NCHRP has an extensive mailing list for publications like this one. Additional distribution through organizations such as TRB, ITE, AASHTO, APTA, ASCE, *ITS America*, APA, and other groups may also be appropriate.

Use of the Manual at National, State, and Local Training Sessions

The *HOV Systems Manual* will be incorporated into training sessions sponsored by TRB, FHWA and FTA, states, and local agencies. The Manual will also be used in the FHWA-sponsored HOV training courses currently in preparation. These courses, which include 1-day, 2-day, and 3-day formats, are being designed around the *HOV Systems Manual*. The Manual will be the source book for the training sessions.

In addition, the Manual will be used at the training sessions held in conjunction with the international conferences sponsored by the TRB HOV Systems Committee. Further, the Manual can be used at training sessions sponsored by state and local agencies and groups. Additional support materials—such as overheads and slides—could be provided to assist with these sessions. These outreach activities would help transfer the research results to a wider audience of practitioners and policy makers.

The potential use of video conference training sessions will also be explored. Video conferencing technologies could be used to link into a scheduled training sessions, or a special training effort could be conducted focused on video conferencing. The opportunity to use video conferencing can be examined by agencies and groups interested in delivering or obtaining the various training sessions.

HOV Web Site

The TRB HOV Systems Committee is currently developing an HOV web site or home page on the Internet. Information on the availability of the manual, how to obtain copies, and the contents of the Manual will be included on the web site. Portions of the Manual may also be highlighted and notification of updated chapters and other revisions, upcoming training courses, national conferences, additional HOV-related reports, ongoing research projects, and other information will be included.

HOV Systems Manual on CD-ROM

The potential of publishing and distributing the *HOV Systems Manual* on CD-ROM will be explored. The use of CD-ROMs is becoming much more widespread. For example, the papers from the 1997 ITE Annual Meeting were available only on CD-ROM. Potential funding for transferring the *HOV Systems Manual* from printed copy to CD-ROM format will be explored. Approaches for selling or distributing the CD-ROM will also be examined.

Video to Support the *HOV Systems Manual*

The development of a video to support the *HOV Systems Manual* will be explored. The video could highlight the various elements addressed in the Manual, including the experience with various types of HOV facilities, developing HOV policies, and planning, designing, implementing, marketing, operating, enforcing, and evaluating HOV projects. Depending on available funding, consideration could be given to a shorter video for policy makers and a longer video for technical staff.

National Conferences and Publications

Technical papers and presentations based on the *HOV Systems Manual* and other results of the research study will be prepared for presentation at TRB, ITE, AASHTO, APTA, APA, ASCE, and *ITS America* meetings as appropriate. Articles will be prepared and submitted to professional journals and publications. All of these activities will help promote widespread distribution of the research results.

Use of Manual in Graduate and Undergraduate Courses

To help ensure that the *HOV Systems Manual* and the results of the research study are transferred to future generations of practitioners, the Manual will be made available to professors teaching graduate and undergraduate courses in transportation planning, engineering, and operations, as well as other related fields. Funding will also be sought to develop specific course materials, lectures, overheads, slides, and videos for the graduate and undergraduate levels.

UPDATING THE *HOV SYSTEMS MANUAL*

The *HOV Systems Manual* prepared under this research study provides a comprehensive guide to developing policies, planning, designing, implementing, marketing, operating, enforcing, and evaluating various types of HOV facilities. The Manual includes information on the these topics to assist

TABLE 10 Updating the *HOV Systems Manual*

Steps	Responsibility
Ongoing Updates	
• Include Requirement for Updated Section of HOV Manual in RFP or Scope-of-Work	• Sponsoring Agency or Group
• Prepare Draft Update	• Contractor
• Review Draft Update	• Sponsoring Agency or Group and TRB HOV Systems Committee
• Finalize Update	• Contractor
• Publish Update	• NCHRP
Five-Year Review	
• Comprehensive Review and Identification of Additional Research, Emerging Issues, and Project Updates	• TRB HOV Systems Committee
• Initiate Update	• NCHRP and Other Funding Sources

professionals and policy makers to plan, design, and operate efficient and effective HOV projects.

As documented in the section on additional research needs, there are still many questions and issues to be examined related to HOV facilities. Original research on these topics was beyond the scope of this study. The evolving nature of transportation issues, as well as new problems and opportunities, will require continued research.

For these reasons, the *HOV Systems Manual* should be updated on a regular basis. As highlighted in Table 10, the recommended process contains two major components. First, the results of new research should be added to the Manual. Second, the Manual should be reviewed every 5 years to determine major update needs. The TRB HOV Systems Committee should play a key role in both these activities.

It is recommended that the results of the additional research projects identified previously and other relevant studies be incorporated into the Manual on an ongoing basis. These updates should be completed as soon as possible after the new information is available to facilitate the technology transfer process and to ensure that professionals and policy makers have access to the most up-to-date information.

To facilitate the update process, and to ensure conformity, it is recommended that a new or revised section of the *HOV Systems Manual* be one of the required deliverables for every research project. This requirement should be included in the request for proposal (RFP) or other statement of work issued on future research projects.

The updated or new sections should follow the format in the current manual. To help ensure the quality and usefulness of the updated sections, it is recommended that the TRB HOV Committee review each new or revised section prior to publication.

The dissemination of the updated sections would be part of the normal NCHRP process. Special efforts should also be made to assist in the dissemination process. These include maintaining a list of all groups and individuals purchasing a Manual, sending out notices on the availability of updates, using the TRB HOV Committee web site, newsletter, and other methods.

In addition, it is recommended that the TRB HOV Systems Committee review the full *HOV Systems Manual* every 5 years. This review should focus on identifying new and emerging trends, developing additional research problem statements, and updating project information. The results of this review would be specific recommendations on updating chapters or sections and additional research studies. These recommendations would be provided to TRB, NCHRP, TCRP, FHWA, FTA, and other agencies for initiating the update process.

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APPENDIX A

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APPENDIXES B THROUGH E

UNPUBLISHED RESEARCH

Appendixes B through E as submitted by the research agency are not published herein. They are available for loan on request to NCHRP. Their titles are as follows:

Appendix B: Practioner Survey Form

Appendix C: List of Respondents
Appendix D: HOV Systems Survey Results
Appendix E: Suggestions from Participants at the 1996 International HOV Systems Conference