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HOVpfs

High Occupancy Vehicle Pooled Fund Study

HOV Performance Monitoring, Evaluation, and Reporting Handbook

January 2006

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16. Abstract

This handbook provides a comprehensive guide to developing and conducting high-occupancy vehicle (HOV) performance monitoring programs. The handbook presents information on monitoring, evaluating, and reporting on the performance of HOV lanes, including projects that allow high-occupancy toll (HOT) vehicles and low-emission and energy-efficient vehicles.

The handbook describes the federal interest in HOV performance monitoring programs and the agencies typically involved. The uses and benefits of information generated from HOV performance monitoring programs is discussed. Common objectives for HOV facilities and related measure of effectiveness and data requirements are presented.

The data collection techniques associated with HOV performance monitoring programs are described, along with the data reduction and analysis techniques. The frequency of data collection, potential funding sources, and staffing and resource needs are highlighted. Approaches for reporting information on the performance of HOV lanes to different stakeholder groups are summarized.

Case study examples are used throughout the document highlighting key points. More detailed information is also presented on selected HOV performance monitoring program case studies.

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CHAPTER ONE – INTRODUCTION

Welcome to the Handbook

Welcome to the *HOV Performance Monitoring, Evaluation, and Reporting Handbook*. This handbook provides a comprehensive guide to monitoring, evaluating, and reporting on the performance of high-occupancy vehicle (HOV) facilities. The goals of the handbook are to advance the state-of-the-practice in monitoring and evaluating HOV facilities and to enhance the management and operation of HOV systems based on the results of these programs.

> The goal of the HOV Pooled-Fund Study (HOV PFS) is to assemble regional, state, and local agencies, and the Federal Highway Administration (FHWA) to:
> - identify issues that are common among agencies;
> - suggest projects and initiatives;
> - select and initiate projects;
> - disseminate results;
> - assist in solution deployment; and
> - track innovations and practice.
>
> Participating state transportation agencies include California, Georgia, Maryland, Massachusetts, Minnesota, New Jersey, New York, Tennessee, Virginia, and Washington.

The handbook is a one-stop reference for transportation professionals. It is also of benefit to policy makers responsible for funding transportation facilities.

The handbook is intended to meet the needs of various audiences. The primary audience of the handbook is transportation professionals responsible for planning, designing, funding, operating, enforcing, monitoring, and managing HOV facilities. The secondary audience includes agency management personnel, policy makers, and other individuals interested in the effective and efficient operation of HOV lanes.

The *HOV Performance Monitoring, Evaluation, and Reporting Handbook* is one of the projects sponsored by the HOV Pooled-Fund Study (PFS) group and the Federal Highway Administration (FHWA). Participating state transportation agencies include California, Georgia, Maryland, Massachusetts, Minnesota, New Jersey, New York, Tennessee, Virginia, and Washington. Other handbooks of interest to transportation professionals and policy makers sponsored by the PFS group include the *HOV Eligibility Requirements and Operating Hours Handbook*, the *HOV Lane Safety Considerations Handbook*, and the *HOV Lane Enforcement Handbook*.

The *HOV Performance Monitoring, Evaluation, and Reporting Handbook* was developed by researchers at the Texas Transportation Institute (TTI), a part of The Texas A&M University System. Battelle acted as the prime contractor on the project. The PFS team, composed of representatives from the participating states and FHWA, oversaw the development of the handbook. The PFS team provided direction on the content of the handbook and reviewed the draft annotated outlines and the draft handbook.

This chapter presents the user-friendly features of the handbook. It also highlights the major topics covered in each chapter to help users find the sections of interest to them.

Handbook Features

The handbook includes a number of user-friendly features. The following icons are used throughout the handbook to highlight the handbook at-a-glance and chapter-at-a-glance, good ideas, keys to successful practices, and case study examples.

This icon highlights **at-a-Glance** previews of the handbook and each chapter.

This icon highlights **Good Ideas** based on experience with HOV performance monitoring, evaluation, and reporting programs.

This icon highlights **Keys to Successful Practices** related to monitoring, evaluating, and reporting on the performance of HOV facilities.

This icon highlights **Case Study Examples** of HOV performance monitoring, evaluation, and reporting programs. More detailed information on comprehensive case studies is provided in Chapter Nine.

Chapters-at-a-Glance

Chapter Two – Executive Summary

This chapter provides a summary of the handbook. It begins with an overview of HOV facilities and highlights the major topics addressed in the remaining chapters. The primary audience for this chapter is policy makers and agency management personnel, although it is appropriate for all groups interested in HOV facilities.

Chapter Three – Developing HOV Performance Monitoring Programs

This chapter provides background information on the development of HOV performance monitoring programs. It summarizes the federal interest in monitoring and evaluating HOV facilities. The chapter describes the uses and benefits of HOV performance monitoring programs and the agencies typically involved in these efforts Coordinating with statewide and metropolitan transportation plans in the development of HOV-related goals and objectives is discussed. The steps involved in developing and conducting HOV performance programs are presented.

Chapter Four – HOV System Objectives, Measures of Effectiveness, and Data Requirements

This chapter presents common objectives for HOV facilities throughout the country and related measures of effectiveness. The data requirements needed to assess these measures of effectiveness are identified.

Chapter Five – HOV Data Collection

This chapter describes the data collection techniques associated with monitoring the performance of HOV facilities. It presents information on the different methods to collect needed data and highlights case study examples from HOV projects throughout the country.

Chapter Six – Data Reduction and Analysis Techniques

This chapter describes elements to consider in archiving, storing, and managing data collected in HOV performance monitoring programs. Data reduction and processing, including methods to address potential data quality control issues, are highlighted. Data analysis techniques frequently used with HOV objectives and measures of effectiveness are presented.

Chapter Seven – Conducting Ongoing HOV Performance Programs

This chapter discusses developing and conducting HOV performance monitoring programs. It presents information on developing and implementing a data collection program, the frequency of data collection, potential funding sources, and staffing and resource needs.

Chapter Eight – HOV Performance Reporting

This chapter describes approaches for reporting information on HOV system performance to various stakeholder groups. It summarizes how the information is used by different stakeholders in developing policies, funding, planning, designing, operating, managing, and enforcing HOV lanes. Reporting methods highlighted include on-line data, technical reports, fact sheets, brochures, PowerPoint presentations, the Internet, and videos and DVDs. The different methods that may be appropriate for presenting information to various stakeholder groups are highlighted.

Chapter Nine – Case Studies

This chapter highlights examples of HOV performance monitoring, evaluation, and reporting programs in use throughout the country. The case studies illustrate approaches and techniques described in the handbook. Case studies from Houston, northern Virginia, the Puget Sound Region, Los Angeles, Minneapolis, and San Diego are described.

Appendix A – References and Additional Resources

This appendix contains the references used in the handbook. It also provides additional resources related to topics associated with HOV performance monitoring, evaluation, and reporting.

Appendix B – Glossary of Terms

This appendix contains a glossary of terms associated with HOV performance monitoring, evaluation, and reporting. It focuses on terms used in the handbook.

Appendix C – List of Abbreviations

This appendix contains a list of abbreviations associated with HOV performance monitoring, evaluation, and reporting. It focuses on abbreviations used in the handbook.

Appendix D – Agency Contacts

This appendix contains contact information for agency personnel participating in the HOV Pooled-Fund Study.

CHAPTER TWO – EXECUTIVE SUMMARY

Chapter-at-a-Glance

This chapter provides an overview of HOV facilities and highlights the major topics presented in the handbook. The chapter contains the following sections.

- **Defining HOV Facilities**. This section provides an overview of HOV facilities in operation in North America. It highlights the role of HOV lanes and the types of facilities in operation.
- **Developing HOV Performance Monitoring Programs**. This section summarizes the federal interest in monitoring and evaluating HOV facilities. It describes the uses and benefits of HOV performance monitoring programs, the agencies typically involved in these efforts, and coordination with statewide and metropolitan transportation plans. The steps involved in developing and conducting HOV performance programs are presented.
- **HOV System Objectives, Measures of Effectiveness, and Data Requirements**. This section summarizes common objectives for HOV facilities throughout the country and related measures of effectiveness. The data requirements associated with these measures of effectiveness are also identified.
- **Data Collection Techniques**. This section highlights the data collection techniques associated with monitoring the performance of HOV facilities. Information on the different methods to collect needed data is presented.
- **Data Reduction and Analysis Techniques**. This section summarizes elements to consider in archiving, storing, and managing data collected in HOV performance monitoring programs, including methods to address potential data quality control issues. Data analysis techniques frequently used with HOV objectives and measures of effectiveness are presented.
- **Conducting Ongoing HOV Performance Monitoring Programs**. This section presents information on developing and implementing data collection programs, the frequency of data collection, potential funding sources, and staffing and resource needs.
- **HOV Performance Reporting**. This section summarizes approaches for reporting information on HOV system performance to various stakeholder groups. The use of information by different stakeholders is described, along with potential reporting methods.
- **Case Study Examples**. This section summarizes examples of HOV performance monitoring programs in use throughout the country. The case studies illustrate the use of different objectives, measures of

effectiveness, data collection techniques, analysis methodologies, and reporting approaches.

Defining HOV Facilities

HOV facilities represent one approach used in metropolitan areas throughout the country to help improve the people-moving capacity rather than vehicle-moving capacity of congested freeway corridors. The travel time savings and improved trip time reliability offered by HOV facilities provide incentives for individuals to change from driving alone to carpooling, vanpooling, or riding the bus.

The development and operation of HOV facilities have evolved over the past 30 years. The opening of the bus-only lane on the Shirley Highway (I-395) in northern Virginia/ Washington, D.C. in 1969 and the contraflow bus lane on the approach to the New York-New Jersey Lincoln Tunnel in 1970 represents the first freeway HOV applications in the country. Today there are some 130 HOV freeway projects in the 31 metropolitan areas in North America highlighted in Figure 2.1.

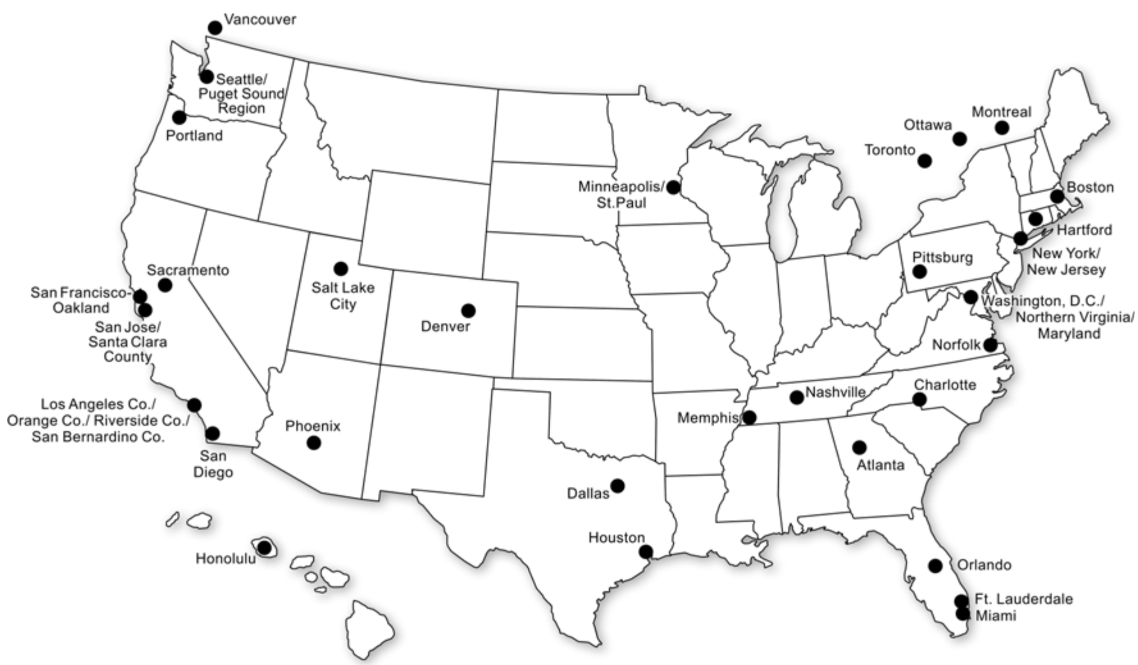


Figure 2.1. Metropolitan Areas with Freeway HOV Facilities.

HOV facilities are developed and operated to provide buses, carpools, and vanpools with travel time savings and more predictable travel times to encourage individuals to choose one of these modes over driving alone. As illustrated in Figure 2.2, the person movement capacity of a roadway increases when more people are carried in fewer vehicles. HOV facilities are usually found in heavily congested corridors where the physical and financial feasibility of expanding the roadway is limited.

Supporting services, facilities, and incentives are also used to further encourage individuals to carpool, vanpool, or ride the bus.

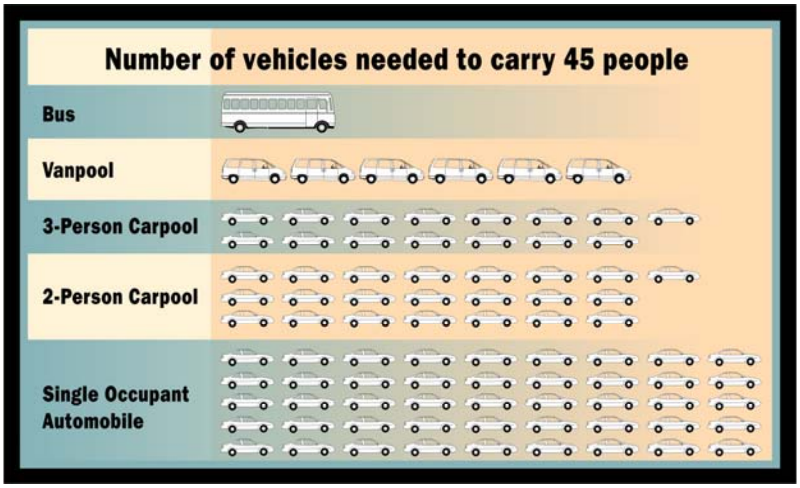


Figure 2.2. Number of Vehicles Needed to Carry 45 People.

Rather than creating disincentives to discourage drivers who travel alone, HOV lanes are developed to provide a cost-effective travel alternative that commuters will find attractive enough to change from driving alone to taking the bus, carpooling, or vanpooling.

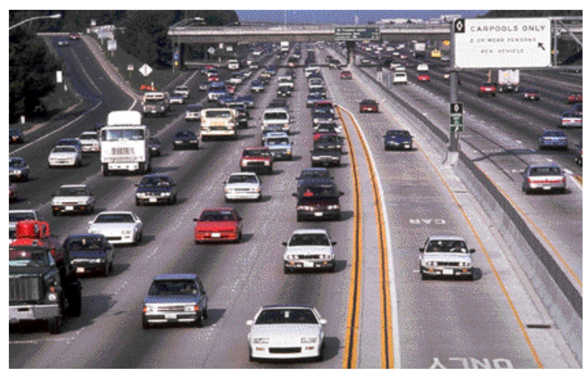
HOV facilities on freeways or in separate rights-of-way are typically classified into four categories. These categories are described below and illustrated in Figure 2.3.

- **Busway or Exclusive HOV Facility, Separate Right-of-Way**. A roadway or lane(s) developed in a separate right-of-way and designated for the exclusive use by high-occupancy vehicles. Most facilities of this type are designed and utilized by buses only. Most are two-lane, two-direction facilities. Busways are in operation in Pittsburgh, Miami, Minneapolis/St. Paul, and Ottawa, Canada.
- **Exclusive HOV Facility, Freeway Right-of-Way**. A lane(s) constructed within the freeway right-of-way that is physically separated from the general-purpose freeway lanes and used exclusively by HOVs for all, or a portion, of the day. Most exclusive HOV facilities are physically separated from the general-purpose freeway lanes by a concrete barrier, but a few facilities are separated by a wide painted buffer. Facilities of this type are usually open to buses, vanpools, and carpools. Exclusive HOV lanes are in operation in Houston, northern Virginia, Minneapolis, San Diego, and Los Angeles.
- **Concurrent HOV Flow Lane**. A freeway lane in the peak direction of travel, not physically separated from the general-purpose freeway traffic lanes, designated for the exclusive use by HOVs for all or a portion of the day. Concurrent flow lanes are usually, although not always, located on the inside lane or shoulder. Paint striping is a common means used to delineate these lanes. HOV facilities of this type are usually open to

buses, vanpools, and carpools. This is the most common type of HOV lane, with projects in operation in Seattle, the San Francisco Bay Area, Los Angeles and Orange County, Denver, Salt Lake City, Phoenix, Dallas, Houston, Minneapolis, Atlanta, Miami and Ft. Lauderdale, Orlando, northern Virginia, Maryland, New York/New Jersey, and other areas.

- **Contraflow HOV Lane**. A freeway lane in the off-peak direction of travel, commonly the inside lane, designated for exclusive use by HOVs traveling in the peak direction. The lane is typically separated from the off-peak direction general-purpose freeway travel lanes by some type of changeable treatment, such as plastic posts or pylons that can be inserted into holes drilled in the pavement, or a moveable barrier. Contraflow lanes are usually operated during the peak periods only; many operate only during the a.m. peak period and then revert back to normal use in non-peak periods. Contraflow HOV lanes may be open to buses-only, buses and vanpools-only, or may also allow carpools. Examples of this type of facility include the approach to the Lincoln Tunnel on Route 495, the Long Island Expressway, and the Gowanus Expressway; all of these are located in the New York/New Jersey area. A moveable barrier is used to create a contraflow lane on the I-30 (East R.L. Thornton) Freeway in Dallas and the Southeast Expressway in Boston.

Exclusive – US 290, Houston, TX



Concurrent Flow – I-405 Orange County, CA

Busway – East Transitway, Ottawa

Contraflow – I-30, Dallas, TX

Figure 2.3. Categories of HOV Facilities.

Many of the initial HOV lanes were bus-only applications or allowed buses and vanpools. In an effort to maximize use, carpools became the dominant use group on most projects during the 1970s and 1980s. The vehicle-occupancy requirements for carpools have evolved over time. A three-person per vehicle (3+) occupancy level was initially used on many projects, but most current facilities use a two-person per vehicle (2+) carpool designation.

More recently, value pricing projects including high-occupancy toll (HOT) lanes, have been implemented. These approaches are part of a broader managed lanes concept that employs market forces to help maximize use of the facilities. Value pricing and HOT lanes allow single-occupant or lower occupancy vehicles to use an HOV lane for a fee, while maintaining free travel to qualifying HOVs. The I-15 FasTrack™ Express Lanes in San Diego and the I-394 MnPASS program in Minneapolis allow single-occupant vehicles to use the HOV lanes for a fee, while the QuickRide program on the I-10 West and US 290 HOV lanes in Houston allows access by 2+ carpools for a fee during the 3+ restricted period.

Developing HOV Performance Monitoring Programs

Federal Interest in Monitoring and Evaluating HOV Facilities

Federal agencies, primarily FHWA and the Federal Transit Administration (FTA), are interested in HOV performance monitoring for a number of reasons. Federal funding is typically used to support the design, right-of-way acquisition, construction, and operation of freeway HOV lanes and busways. As a result, FHWA and FTA have an interest in maintaining the federal investment in these facilities and in maximizing the effective and efficient use of HOV lanes.

Provisions of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) require that the agencies responsible for operating HOV lanes conduct monitoring programs if certain exempt vehicles are allowed to use the lanes. These exempt categories include tolled vehicles and low-emission and energy-efficient vehicles. The operating agency is required to limit or discontinue use of the HOV lane by these vehicles if allowing access has degraded the operation of the HOV lane. The operation of an HOV lane is defined as being degraded if vehicles using the facility fail to maintain a minimum average operating speed 90 percent of the time over a consecutive 180-day period during the morning or evening weekday peak-hour periods. The minimum operating speeds are defined as 45 mph when the posted speed limit is 50 mph or greater and not more than 10 mph below a posted speed limit of less

FHWA provides periodic HOV Program Guidance to support the federal investment in freeway HOV facilities and to help promote their effective use, while maintaining the intent of maximizing the person-movement capacity. The Guidance supports performance monitoring programs, which provide the information needed to make sound decisions on operating HOV facilities.

than 50 mph. Additional information on monitoring requirements is available in the FHWA HOV Program Guidance.

Uses and Benefits of HOV Performance Monitoring Programs

The results of HOV project evaluations are of interest to a variety of individuals and groups. These groups include agency operation and management personnel, federal agency staff, decision makers, special interest groups, the media, and the general public.

Multiple benefits may be realized from HOV performance monitoring programs. Performance information supports the ability to determine if the goals and objectives of a project are being achieved. Performance monitoring also provides information needed to make operating decisions, including changes in the operation of an HOV facility. Information from HOV monitoring programs is also of use in planning future projects. Communicating the use and benefits of HOV facilities to the public and to policy makers is also important.

Transportation Plans and HOV Systems

Coordinating HOV performance monitoring programs with related efforts of the state department of transportation, the MPO, the public transportation agency, and other appropriate agencies and groups in a metropolitan area is important. The development of goals and objectives related to the HOV system are guided by the missions, goals, and objectives of these agencies and the goals and objectives outlined in the appropriate transportation and transit plans. These plans include the long-range statewide and metropolitan transportation plans required by federal law, long-range and short-range public transportation plans, regional plans, and corridor or facility-specific plans. As illustrated in Figure 2.4, these plans provide guidance in developing HOV goals and objectives for the HOV performance monitoring program.

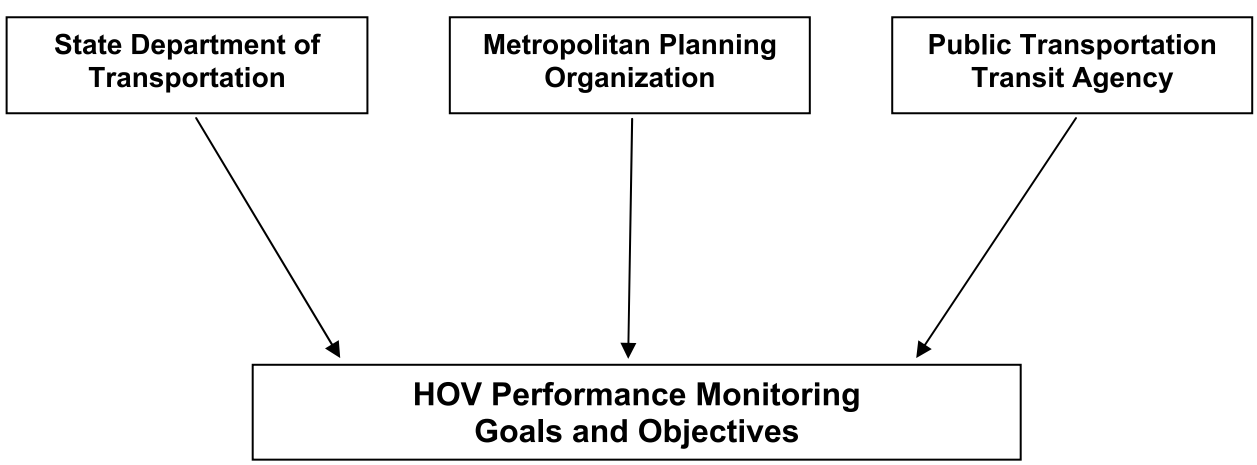


Figure 2.4. Relationship of HOV Performance Monitoring Goals and Objectives to State and Metropolitan Goals and Objectives.

Agencies Involved in HOV Performance Monitoring Programs

The agencies typically involved with HOV performance monitoring, evaluation, and reporting include state departments of transportation, public transportation agencies, MPOs, and state and local law enforcement agencies. Depending on the type of HOV facility, cities and counties may also participate. Representatives from FHWA and FTA are frequently involved. In addition, representatives from rideshare agencies, regional organizations, and the judicial system may participate in multi-agency teams and may assist with HOV performance monitoring activities.

> A key to the success of many HOV projects, including HOV performance monitoring programs, is the involvement of personnel from all appropriate agencies and groups. Multi-agency teams are often used in planning, designing, implementing, operating, and monitoring HOV facilities. Multi-agency teams help ensure that the objectives and measures of effectiveness focus on major project goals, that the appropriate data collection and analysis techniques are used, and that the results are provided to key groups Multi-agency teams can also facilitate shared funding and data collection responsibilities for HOV performance monitoring programs.

HOV Performance Monitoring Process

HOV performance monitoring programs follow the same process used to evaluate any transportation project. As illustrated in Figure 2.5, the first step in the process is to identify the goals and objectives for the HOV facilities in an area. These goals and objectives should flow from those articulated in state, metropolitan, and local transportation policies and plans. Measures of effectiveness are then identified for each objective, along with the corresponding data requirements. Data collection efforts are undertaken and the results are processed and analyzed. The results of the monitoring and analysis process are reported to the various stakeholder groups through a variety of methods. The results are used to make operating decisions, to determine if the project objectives are being met, and to enhance future planning activities and investment decisions.

Following this general approach will result in the development, implementation, and conduct of a meaningful HOV performance monitoring program. While some elements of this approach may vary in different areas, the basic procedures are appropriate for consideration in monitoring and evaluating all types of HOV facilities.

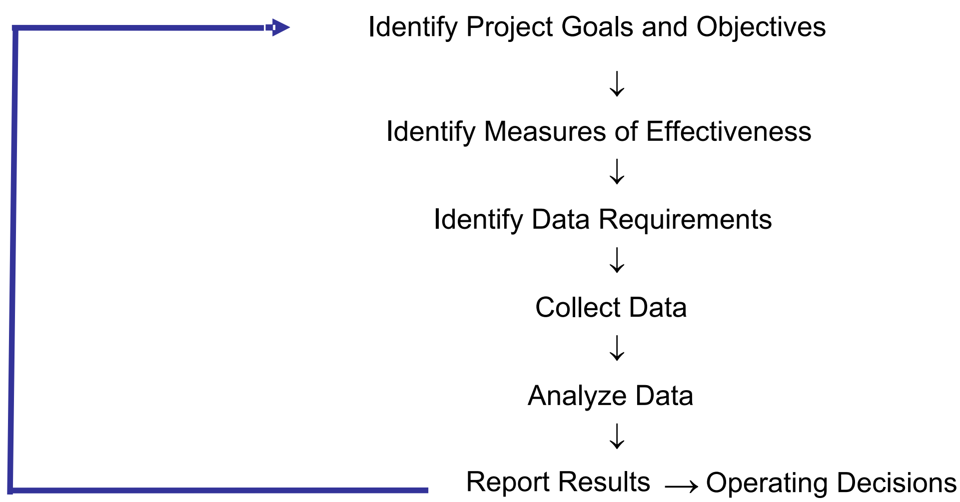


Figure 2.5. Steps in Developing and Conducting an HOV Performance Monitoring Program.

HOV Objectives and Measures of Effectiveness, and Data Requirements

HOV Objectives and Measures of Effectiveness

The first step in the development of an HOV performance monitoring program is to ensure that there is agreement on the project goals and objectives. It is important to ensure that the objectives are measurable, as the remainder of the evaluation program will focus on gathering and analyzing information to determine if the objectives have been met.

After the objectives have been clearly defined, the next step is to identify the appropriate measures of effectiveness or evaluation criteria that correspond to each objective. These measures should focus on the key elements of the objectives, so that the information needed to determine if the objective has been achieved can be collected and analyzed.

Measures of effectiveness used with the objective of improving the capacity or throughput of a congested travel corridor include the percent increase in average vehicle occupancy (AVO), and the percent increase in vanpools, carpools, and bus riders. Measures of effectiveness for the objective of providing travel time savings and trip time reliability to HOVs using the HOV lane focus on peak-direction, peak-period travel time savings by using the HOV lane over the general-purpose freeway lanes and improved trip time reliability.

National Overview of Typical HOV System Objectives

An FTA-sponsored research project in the early 1990s examined before-and-after studies completed on HOV projects in the U.S. This information was updated during the development of the NCHRP *HOV Systems Manual* in the late 1990s. The following nine objectives were identified as examples of HOV objectives used by different agencies in the country.

- The HOV facility should improve the capability of a congested freeway corridor to move more people by increasing the number of persons per vehicle.
- The HOV facility should increase the operating efficiency of bus service in the freeway corridor.
- The HOV facility should provide travel time savings and a more reliable trip time to high-occupancy vehicles utilizing the facility.
- The HOV facility should not unduly impact the operation of the general-purpose freeway lanes.
- The HOV facility should increase the per lane efficiency of the total freeway facility.
- The HOV facility should be safe and should not unduly impact the safety of the general-purpose freeway lanes.
- The HOV facility should have public support.
- The HOV facility should be a cost-effective transportation improvement.
- The HOV facility should provide favorable impacts on air quality and energy consumption.

Data Requirements

The measures of effectiveness are assessed by collecting and analyzing data on different elements related to the performance of the HOV lanes, the general-purpose freeway lanes, and supporting facilities and services. The data requirements typically associated with various measures of effectiveness are summarized below.

- Updated HOV facility inventory.
- Vehicle volumes by type of vehicle in the HOV lanes and general-purpose freeway lanes.
- Vehicle occupancy counts in the HOV lanes and general-purpose freeway lanes.

- Travel times in the HOV lanes and general-purpose freeway lanes.
- Travel speeds in the HOV lanes and general-purpose freeway lanes.
- Trip time reliability in the HOV lanes and general-purpose freeway lanes.
- Bus ridership levels in the HOV lanes and general-purpose freeway lanes.
- Park-and-ride and park-and-pool lot use.
- Occupancy violations, access violations, pricing violations, and other violations.
- Number and nature of crashes in the HOV lanes and general-purpose freeway lanes.
- Perceptions of users, non-users, the public, and policy makers.
- Measures relating to vehicle emissions and air quality.
- Measures relating to capital and operating costs.

HOV Data Collection

HOV Facility Inventory

An up-to-date inventory of HOV facilities in an area should include information on the location and lengths of HOV lanes, access points, operating hours, vehicle eligibility requirements, vehicle-occupancy levels, and other key features. This information may be maintained in table format, as part of a geographic information system (GIS), or as part of another database. Information on park-and-ride and park-and-pool lots, bus routes, and other supporting elements, may also be included in the inventory.

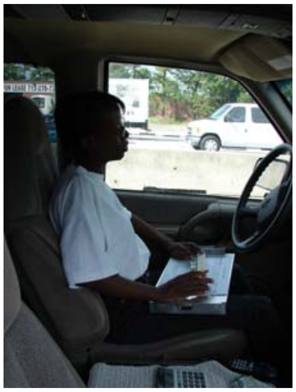
Vehicle and Vehicle-Occupancy Counts

Data on vehicle volumes and vehicle classification are usually obtained either through special field surveys or from advanced transportation management systems or other technology-based systems. Vehicle volumes and vehicle classification data is needed for the HOV facility and the general-purpose freeway lanes. Consideration should also be given to conducting counts along freeway frontage roads, if they exist in the corridor, and a freeway without an HOV to provide a control facility. The manual count technique relies on field personnel counting vehicles by type for the HOV and general-purpose freeway lanes. In some metropolitan areas, data on vehicle volumes and vehicle classification may be available from advanced transportation management systems or other technology-based systems.

Vehicle-occupancy counts are usually conducted at the same locations as the vehicle volumes and vehicle classifications counts, although different sites may be used to ensure the safety of field personnel. The count site should provide field personnel with a clear view of as much of the vehicle interior as possible and a safe environment. Field staff record the type of vehicle and the number of occupants for a specific lane – HOV and general-purpose – for a specific time period, typically in 15-minute increments. The counts are recorded using traffic counters, data forms, or computers.

The number of HOT or toll-paying vehicles using an HOV lane is obtained from the toll collection records. Electronic toll collection (ETC) transactions are automatically recorded. The number of transactions for a specific time period are obtained from the operator.

Vehicle-Occupancy Counts



Vehicle-occupancy counts in Houston are conducted by personnel in vans located a strategic points along the HOV lanes and general-purpose freeway lanes. The data collection sites are selected to provide unobstructed views of vehicles and to provide safe locations for field personnel.

Low-emission and energy-efficient vehicles, and other exempt vehicles, are typically included in the vehicle classification counts. Depending on the state, low-emission and energy-efficient vehicles must have special license plates or decals. It may be difficult to distinguish these vehicles depending on the type of marking required. Special counts may be conducted focusing on just these vehicles at locations where the license plates or decals can be seen.

Travel Time and Travel Speed Data

Travel time data measures the time it takes a vehicle to travel a certain distance. Travel time data are collected for the HOV lane and the general-purpose freeway lanes so that comparisons can be made related to travel time savings from using the HOV lanes. A number of methods may be used to collect travel time data. The traditional method, typically called the test vehicle, floating car, or maximum car technique, involves a test vehicle making a number of trips in the HOV lane and the general-purpose freeway lanes. To conduct travel time runs, two people per vehicle are needed: one to drive and one to monitor the stopwatch and record the results or to operate the computer and the electronic distance measuring instrument (DMI) or global positioning system (GPS). The test vehicles travel at the average speed of other traffic without exceeding the speed limit. Ideally, travel time runs should be conducted during the same time periods for the HOV lane and the general-purpose freeway lanes, requiring two-to-four test vehicles.

The use of intelligent transportation systems (ITS), including advanced transportation management systems (ATMS) and transportation management centers (TMCs), provides opportunities in some areas to obtain travel time and travel speed data from these systems. Archived data from traffic operations systems may be used to compute travel speeds or travel times in HOV lanes and general-purpose freeway lanes.

Bus Routes and Ridership

Information on bus routes, services, the frequency of service, the number of buses, and the type of buses can be obtained from the public transportation agency or agencies in the area. Information can also be obtained from private bus operators, charter services, and school districts if they operate service on the HOV lanes. These agencies and operators can also provide ridership information. In addition, bus ridership is typically estimated during the vehicle-occupancy counts noted previously.

Park-and-Ride and Park-and-Pool Lot Use

Information on the use of park-and-ride and park-and-pool facilities is typically obtained through periodic manual counts. Usually, the number of vehicles parked at each facility is recorded during the middle of the day (between 9:00 a.m. and 3:00 p.m.) on weekdays.

HOV Facility User and Non-User Surveys, Focus Groups, and Interviews

A variety of market research techniques may be used to obtain information on the previous mode of carpoolers, vanpoolers, and bus riders, as well as perceptions about HOV lanes from users and non-users. These techniques include focus groups, telephone and mail out/mail back surveys, Internet surveys, on-board surveys of bus riders, and interviews with key stakeholders. Focus groups may be conducted with individuals from different user groups to gain insights on perceptions relating to HOV lanes, possible changes in operation, and potential public information strategies. Mail surveys may be used to obtain information from carpoolers, vanpoolers, and motorists in the general-purpose freeway lanes. Typically, license plate numbers of vehicles using the HOV lanes and the general-purpose freeway lanes are recorded, the addresses of the registered owners are obtained from the appropriate state agency, and surveys are mailed to these individuals. Mail surveys typically contain questions about current and previous travel modes, trip characteristics, and socio-economic information. Similar surveys are conducted of bus riders by distributing surveys to passengers as they board buses and collecting them as they exit at the end of the trip. Other techniques include intercept surveys with bus riders and park-and-ride and park-and-pool lot users, interviews with key stakeholders, Internet surveys, and telephone surveys.

Surveys of HOV Lane Users and Non-Users

Numerous surveys of users and non-users of the Houston HOV lanes have been conducted over the years, including surveys of bus riders. Questionnaires are distributed to passengers as they board buses at park-and-ride lots and are collected by personnel riding the buses.

Crash Data

Crash data for the HOV lanes, in the adjacent general-purpose freeway lanes, and on the control freeways is needed to assess measures of effectiveness related to safety. In most areas, crash information is obtained from the state department of transportation, the state or local department of public safety, and the state, local, or transit enforcement agency. Ensuring that similar techniques are used to collect and analyze crash data is important. For example, variations may exist in the methods used to record crashes by different agencies in the same corridor. Further, it is often difficult to determine the exact cause of a crash and the exact location.

Violation Rates

The violation rates, which reflect the number of vehicles not meeting the minimum HOV lane occupancy requirements, provide a general indication of the degree of public understanding and support for the facility and if the facility is being used for the intended purpose. Violation rates are typically monitored in different ways. The number of citations issued by the agency responsible for enforcing the HOV lanes provides one measure. The state, local, or transit police are typically responsible for issuing citations for violation of vehicle-occupancy requirements or other moving violations. Second, the vehicle and occupancy counts provide information on the number of vehicles not meeting the minimum occupancy requirements. Third, with HOT projects, toll violators are recorded by electronic toll collection (ETC). Finally, areas with peer-enforcement programs, such as the HERO program in Seattle, monitor the number of calls received to the telephone hotline.

Data Reduction and Analysis Techniques

Data Archiving, Storage, and Management

To use the data collected through the methods described previously, a process must be established for archiving, storing, and managing the data. It is important that this process be well thought out and documented prior to initiating actual data collection activities. These procedures will guide the data reduction process.

> The accuracy and integrity of data collected as part of an HOV performance monitoring program is critical. Elements in a data quality control program include checking to ensure data are entered and transferred correctly, establishing and applying validity checks to identify suspect or invalid data, reviewing comments from field crews or data collection logs, and identifying and correcting any problems at specific manual or automatic data collection sites.

The data collection methods will influence the data archiving, storage, and management process. The archiving and retention process for data collected through actual field monitoring and observations is different from the process used with data obtained from advanced transportation management systems, which typically requires increased computer capabilities. Key steps in the process include establishing a lead agency, establishing the actual procedures, identifying funding sources, and establishing procedures for accessing and using the data.

Data Reduction and Processing

Data collected in the field or through advanced transportation management systems must be transferred into databases and other software programs for further analysis. Based on the data archiving, storage, and management process, standard procedures should be established and used to transfer data collected in the field or obtained from other sources. These procedures should ensure the integrity and accuracy of the data.

The data collected by the field crews on vehicle volumes, vehicle classification, vehicle-occupancy, travel times, and other measures are usually transferred to office personnel for processing and analysis. Data collected using a manual device and a count form will need to be manually entered into a spreadsheet or database. Data are typically entered by the specific time periods when the counts were conducted. Data collected using computers or other electronic devices are downloaded or transferred into a central computer or database. Data obtained through advanced transportation management systems may be transferred from one computer system to another.

Data Analysis Techniques

Vehicle Volumes

Vehicles volumes for the HOV lane and the general-purpose freeway lanes are presented for the specific points along the corridor where the data is collected. The vehicle volumes are typically summarized for the morning and afternoon peak hours and peak-periods. A 24-hour count may also be provided if the HOV lanes operate on a 24/7 basis. Vehicle volumes per hour per lane are typically reported for the HOV lane and the general-purpose freeway lanes. For the freeway, the number of vehicles using the freeway is divided by the number of lanes to obtain the vehicle volume per hour per lane.

Person Volumes and Person Throughput

Person volumes are the total number of individuals in all vehicles at the specific data collection points for a specific time period. Person volumes may be presented as the persons per hour per lane (pphpl). The pphpl for the morning and afternoon perk hour is calculated by totaling the number of individuals in all vehicles for the specific hour in the HOV lane. The same calculation is performed for the general-purpose freeway lanes. Person volumes for the HOV lane and the general-purpose freeway lanes are presented for the same data collection locations during the same time periods as the vehicle volumes. A comparison is typically made of the person volumes, pphpl, or person throughput on the HOV facility versus the general-purpose freeway lanes. The total person throughput for the facility can also be computed by combining the HOV and general-purpose freeway lanes together.

Average Vehicle-Occupancy

AVO is calculated from the vehicle volume by classification and person throughput data. AVO by vehicle classification, total AVO for the HOV lane, total AVO for the freeway, and total AVO for the facility (HOV and freeway) can be calculated. AVO by vehicle classification is obtained by dividing the person throughput for a specific vehicle type by the number of vehicles in that classification. The total AVO for the HOV lane or the general-purpose freeway lanes is calculated by adding the total occupancy for all vehicles divided by the total vehicles. The AVO in the HOV lanes is compared to the AVO in the general-purpose freeway lanes. A total facility AVO can be calculated by dividing the total person volume for both the HOV and general-purpose freeway lanes by the total vehicle volumes. The AVO is usually carried out to the hundredth of a decimal point (i.e., 1.24).

Travel Times and Travel Speeds

The method for calculating travel times and travel speeds will depend on the data collection technique used. Travel time data collected electronically using the floating car technique is usually processed through a software program that calculates travel time and travel speed and transfers the results to a spreadsheet or database. Travel times collected manually using the floating car technique are manually entered into a spreadsheet or database that is then entered into the software program. Travel time and travel speed data for multiple runs can be averaged and reported for the HOV lane and the general-purpose freeway lanes. Data obtained through advanced transportation management systems typically provides speed data for the HOV lane and the general-purpose freeway lanes. Software programs are used to estimate travel times from the speed data.

Travel Time Savings

Travel time savings measure the amount of time a traveler saves by using the HOV lane rather than the general-purpose freeway lanes for the same trip distance. Travel time savings are calculated by taking the difference in travel times between the HOV and the general-purpose freeway lanes. It is typically presented as the number of minutes saved by vehicles in the HOV lane for a specific trip distance, usually the length of the HOV lane. For example if it takes 30 minutes to travel from point A to point B in the general-purpose freeway lanes and 24 minutes to travel the same distance in the HOV lane, the travel time savings from the HOV lane is 6 minutes.

Travel Time Index

The travel time index is a comparison between the travel conditions in the peak period and travel conditions in freeflow periods. The travel time index formula in Figure 2.6 can be used to provide a travel time index for a freeway or an HOV lane. For example, a value of 1.20 indicates that the travel time during the peak period is 20 percent longer than the travel time during the off-peak period.

$$\text{Travel Time Index} = \frac{\text{Average Peak Period Travel Time}}{\text{Average Off-Peak Travel Time}}$$

Figure 2.6. Formula for Travel Time Index.

Trip Time Reliability

Trip time reliability can be defined as the consistency or the dependability in travel times, as measured from day-to-day and/or across different times of the day. The development of analytical techniques to measure trip time reliability is an emerging practice. Presented next are two measures of reliability – the buffer index and travel speed reliability.

Buffer Index

The Buffer Index, shown in Figure 2.7, is a measure of trip reliability. It expresses the amount of extra time or the "buffer" needed to be on-time for 95 percent of trips made during a certain time, such as the peak period. The 95 percent measure would amount to being late for work or school one day per month. Indexing the measure provides a time and distance neutral measure. The actual minute values could be used by an individual traveler for a particular trip length, however.

$$\text{Buffer Index} = \frac{\text{95th Percentile Travel Time - Average Travel Time}}{\text{Average Travel Time}}$$

Figure 2.7. Formula for Buffer Index.

Travel Speed Reliability

Trip speed reliability provides another possible measure of trip time reliability. A commonly used travel speed reliability measure is the percent of time that travel speeds fall below an average speed of 45 mph. The 45 mph criteria equates to a Level-of-Service (LOS) C for a posted speed limit of 55 mph. Using this measure, travel speed reliability can be assessed for an HOV lane and for the adjacent general-purpose freeway lanes over the same time period, typically the peak hours. Use of this measure is dependent on data available from advanced transportation management systems due to the volume and frequency of travel speeds needed. Data obtained from annual or periodic travel time runs does not adequately capture the day-to-day differences in travel speeds needed for this measure.

Transit Vehicles and Ridership

Information on the number of buses using an HOV facility and ridership levels is usually presented numerically and as a percentage of the total vehicles and persons using the facility. This information is typically analyzed for the morning and afternoon peak hours and the peak-periods. Information on off-peak levels may also be provided if bus services are operated during these time periods. In addition, maintaining maps illustrating the bus routes using the HOV lanes is recommended as they provide an excellent method to highlight service improvements and expanded service coverage.

Transit vehicles and passengers may also be presented as the AVO for transit and as part of total AVO for the HOV facility. The transit AVO is obtained by dividing the total bus ridership by the number of buses for a specific time period. The total AVO for the HOV facility is calculated by adding the number of persons in all vehicles and dividing by the total number of vehicles. The percentage of buses and bus riders that comprise the total vehicle and person volumes in the lane can also be calculated by dividing the number of buses and bus riders by the total number of vehicles and persons.

Park-and-Ride and Park-and-Pool Lot Use

Data on park-and-ride and park-and-pool lot use is presented both as the actual number of vehicles parked at a lot and the percentage of lot utilization. The percent of lot utilization is calculated by dividing the number of parked vehicles by the total number of available parking spaces. The total number of vehicles parked at all lots along an HOV corridor and the total utilization for all lots is also usually presented.

Occupancy Violation Rates

The vehicle-occupancy violation rate, which is typically referred to as the violation rate, measures the number of non-exempt vehicles in the HOV lane not meeting the occupancy requirement. Violation levels on an HOV lane are usually expressed as a rate comparing the number of violators with the total vehicles in the lane. As shown in Figure 2.8, violation rates are expressed as a percentage by dividing the number of vehicles not meeting the occupancy requirement, excluding exempt vehicles, by the total number of vehicles in the lane.

$$\text{Percent of Violators} = \frac{\text{Number of Vehicles Not Meeting Occupancy Requirement}}{\text{Total Number of Vehicles in Lane}}$$

Figure 2.8. Formula for Calculating Vehicle-Occupancy Violation Rate.

Occupancy Violation Citations

The number of citations issued by enforcement personnel to drivers of vehicles not meeting occupancy requirements provides another measure of violation levels. The ability to issue citations is influenced by the presence and level of enforcement on a facility, which may vary over time. As a result, this measure is typically reported as the number of citations issued over a specific time period, with a reference to enforcement levels provided during the reporting periods.

Operating Violation Citations

The numbers of citations issued for violating operating requirements, such as entering or exiting an HOV lane illegally, are typically reported for specific time periods. Citations may be issued for moving violations or other infractions. As noted with citations for occupancy violations, the number of citations issued for operating requirements violations will be influenced by the level of enforcement. Examination of information on the number of operating regulation violations should include an assessment of enforcement levels during the different time periods.

HOT Violations

Non-payment of tolls with HOT projects is monitored by the operating agencies. The number of toll violators may be reported or the toll violation rate may be calculated by dividing the number of non-paying vehicles by the total number of HOT vehicles using the lane for the same time period. Figure 2.9 presents the formula for this calculation.

$$\text{Percent of HOT Violators} = \frac{\text{Non-Paying HOT Vehicles in Lane}}{\text{Total HOT Vehicles in Lane}}$$

Figure 2.9. Formula for Calculating HOT Violation Rate.

Crash Rates

Crash data is often summarized as the number of crashes related to vehicle miles of travel (VMT) or passenger miles of travel. Crash rates measure safety trends or crash potential related to vehicle exposure measured in VMT. Annual vehicle crash rates are calculated as vehicle crashes per 100 million VMT. It is recommended that crash rates be documented for a freeway before the HOV lane is implemented. Crash rates may be examined on an annual basis after the lane is open to attempt to identify the impact of an HOV lane. Given potential limitations with many crash databases however, a lane-by-lane comparison is not usually possible, as crash rates are not typically lane-specific. A general comparison of the crash rates for freeways with HOV lanes to freeways without HOV lanes and to the state average may be appropriate.

Mapping the location of crashes in GIS can help identify potential problem spots. If crashes are clustered in similar areas, these locations can be examined for potential changes in operation or design modifications. Examining crash rates per million passenger miles of travel considers the difference in person throughput of the HOV lane and general-purpose freeway lanes. The crash rates per million passenger miles of travel for the HOV lane and the general-purpose freeway lanes are calculated and compared.

Vehicle Emissions and Air Quality

The potential air quality impacts associated with HOV lanes typically focus on vehicle emissions. There are two analysis approaches that are frequently considered to assess the potential impact of HOV lanes on vehicle emissions. A first approach is to assess vehicle emissions with and without an HOV lane. Emissions in grams of carbon monoxide (CO), oxides of nitrogen (NOx), and particulate matter (PM10) are estimated based on passenger miles traveled with and without the HOV lane. A second approach focuses on air quality models used during the planning process for an HOV lane. If specific air quality models were used during the planning process for an HOV project, these models can be re-run with data from the performance monitoring program.

Benefit-Cost Ratio

The benefit-cost ratio is the analysis technique typically used with objectives relating to a cost-effective transportation improvement. The benefit-cost ratio is defined as the present value of all benefits divided by the present value of all costs. Projects with a benefit-cost ratio of greater than 1.0 are usually considered cost-effective. To calculate a benefit-cost ratio, the capital and operating cost of an HOV project is needed, along with a value (in dollars) of the benefits. It may be difficult, in some cases, to determine the capital cost of an HOV project if it was part of larger freeway improvement project or was implemented a number of years ago. As a conservative estimate, only the travel time savings accrued to users of the HOV lane is often used to calculate the benefit-cost ratio for an HOV project.

Conducting Ongoing HOV Performance Programs

Developing and Implementing a Data Collection Program

The use of sound and consistent data collection techniques is critical to ensure the integrity of an HOV performance monitoring program. Elements to consider in developing and implementing a data collection program include reviewing data requirements and existing data sources, and establishing the data collection techniques, the data collection locations, and the data collection time periods. Other elements focus on identifying a data collection schedule, developing data collection assignments and check lists, conducting training for field personnel and staff, performing pilot test sessions, and conducting the actual data collection efforts.

Frequency of Data Collection and Reporting

The frequency of HOV data collection, analysis, and reporting will be influenced by a number of factors. The type, number, and age of HOV lanes in an area will impact the performance monitoring schedule. Other factors include the data collection techniques used, funding availability, and staff resources. Changes in operations of the HOV lane and anticipated changes will also influence the monitoring schedule.

A base level of data collection, analysis, and reporting matched to common HOV objectives and measures of effectiveness can be identified. For new HOV lanes, before data on vehicle volumes, vehicle classification, vehicle-occupancy, travel time, travel speeds, trip time reliability, bus services and ridership, and crashes should be obtained. If possible, before data should be collected more than once. Establishing a trend line over multiple years is desirable.

Data are typically collected more frequently during the initial operating phase of a new HOV lane or after major changes in operation have occurred. Key data on vehicle volumes and classification, vehicle-occupancy, violations, and crashes may be collected monthly or quarterly during the initial phase of operation. As a facility matures, the data collection schedule typically lengthens, with key data collected quarterly or annually. Surveys of users and non-users may be conducted every two-to-five years. Reporting annually on key performance measures and objectives provides critical information to all stakeholder groups.

Potential Funding Sources

Funding for developing and conducting ongoing HOV performance monitoring programs may come from a variety of federal, state, and local sources. Data collection, monitoring, and evaluation activities are eligible project expenses for HOV lanes constructed using federal funds. These activities may also be funded through federal demonstration projects. Other possible federal sources include metropolitan and statewide planning funds, and state planning and research funds. In addition, federal funding supporting the development and operation of advanced transportation management systems and other related systems supports HOV data collection and analysis efforts.

State departments of transportation, MPOs, public transportation agencies, and local governments often provide the local match required on many federal funding programs, as well as providing additional funding for different aspects of HOV performance monitoring programs. Funding for state gasoline sales taxes, state vehicle taxes, local sales taxes, bonding, and other sources may be used.

Staffing and Resources

The staffing and resources needed to conduct the different elements of ongoing HOV performance monitoring programs will depend on a number of factors. These factors include the number, type, and age of HOV lanes in the area, as well as the data collection techniques, frequency of data collection and analysis, and frequency and method of performance reporting. The approach used to conduct different functions will also influence needed staffing and resources. Possible approaches include conducting all functions within one or more agencies, contracting with a university or university-affiliated group, and contracting with one or more consulting firms.

Typically, one individual at the agency operating the HOV lanes will be responsible for overseeing the HOV performance monitoring program. The level of effort and percentage of overall job responsibilities will depend on the scope of the performance monitoring program. Additional staff, either in-house, with other agencies, or with universities or consulting firms, will be needed for data collection, data reduction, data analysis, and report preparation. The skill sets of these groups are very different.

HOV Performance Reporting

The information generated by HOV performance monitoring programs is of interest and use to numerous stakeholders. These stakeholders include agency staff responsible for operating HOV facilities, agency staff responsible for planning and designing future HOV facilities, federal agency staff and transportation professionals in other areas, agency management personnel, elected and appointed officials, members of the print and electronic media, and the public and special interest groups.

The information presented, the level of detail, and the communication method should be tailored to the needs of the various stakeholder groups. The information presented should focus on the key performance measures. Maintaining consistency among the different reporting approaches can help save staff and financial resources. For example, the same key information and graphics can be used in reports, fact sheets, brochures, PowerPoint presentations, and the Internet with slight changes. The accompanying text can be expanded or reduced as appropriate. A name, telephone number, e-mail address, and Internet sites should be included in all reporting methods for follow-up questions or comments.

Keys to successful reporting on the results of HOV performance monitoring programs include focusing on the most important measures of effectiveness and tailoring information to the needs of different stakeholders, while maintaining consistency in the reporting formats. The scope, content, and level-of-detail should be appropriate to the various stakeholders. These stakeholders include agency technical staff, federal agency staff and transportation personnel in other areas, agency management personnel, elected and appointed officials, the media, and the public. Possible reporting approaches include on-line data, technical reports, fact sheets, brochures, PowerPoint presentations, the Internet, and videos and DVDs. Contact information, including telephone numbers, e-mail addresses, and Internet sites should be included on all reporting methods.

Information should be presented in a clear, concise, and readable manner that allows individuals to easily identify the purpose of the data and the changes that have occurred. A good performance monitoring program can be wasted if the results are poorly presented. Spending adequate time and resources to ensure clear and well-presented reporting is essential.

Table 2.1 highlights the reporting techniques that may be considered with different stakeholders. Potential communication techniques include on-line data, technical reports and summaries, fact sheets, brochures, PowerPoint presentations, the Internet, and videos and DVDs.

Reporting Methods	Stakeholder Groups Local Technical Staff	National Technical Staff/ Researchers	Agency Management Personnel	Elected/ Appointed Officials	Media	Public/ Interest Groups
On-Line Data	√	√				
Technical Reports/ Summaries	√	√				
Fact Sheets	√	√	√	√	√	√
Brochures			√	√	√	√
PowerPoint		√	√	√	√	√
Internet	√	√	√	√	√	√
Video/DVD			√	√	√	√

√ **–** primary audiences.

Table 2.1. Stakeholder Groups and Reporting Methods.

Case Study Examples

Ongoing HOV performance monitoring programs have been conducted in some metropolitan areas for many years. Examples of programs in six areas are summarized here.

Houston

A detailed before-and after assessment of the I-45 North contraflow demonstration project, which was opened in 1979, was conducted. The evaluation procedures, measures of effectiveness, and data collection activities associated with evaluating the effectiveness of the Houston HOV lanes have evolved over the years to take advantage of changes in technology. The Texas Department of Transportation (TxDOT) and the Metropolitan Transit Authority of Harris Count (METRO) have sponsored this effort, although the exact level of funding by each agency has varied. The current monitoring activities are summarized here.

Vehicle and occupancy counts are conducted quarterly on the HOV lanes and the general-purpose freeway lanes. Both vehicle and occupancy counts were initially conducted by field personnel. Tube counters are now used to obtain vehicle counts, while vehicle-occupancy counts are still conducted by field personnel. The number of vehicles parked at the park-and-ride and park-and-pool lots associated with the HOV lanes is also counted quarterly.

Travel time runs were initially conducted on the HOV lanes and adjacent general-purpose freeway lanes using the floating car technique. The data collection method changed after the implementation of TranStar, the advanced transportation management center for the Houston area, and the automated vehicle identification (AVI) system. The speed data from the AVI system is used to estimate travel times for the HOV lanes and the general-purpose freeway lanes. The results are compared and the travel time savings provided to users of the HOV lanes are calculated.

Surveys of bus users, carpoolers, and vanpoolers using the HOV lanes and single occupant vehicles in the general-purpose freeway lanes were conducted on a regular basis during the 1980s and 1990s. Additional surveys were conducted as part of the QuickRide HOT project.

The METRO transit police are responsible for responding to crashes in the HOV lanes. METRO police are also responsible for documenting the crashes and maintaining the crash records. The METRO crash data table includes the date, time, and location of each crash. It also includes the damage rating, comments by the reporting police officer, the driver's age range, and the type of ticket issued.

METRO Transit Police are responsible for enforcing vehicle-occupancy levels and other operating requirements. METRO provides a summary of the violation rates on the HOV lanes. The vehicle and occupancy counts also provide a check on violation rates, which are summarized in the quarterly reports.

A number of methods have been used to report the results of the monitoring activities. These methods include detailed reports, quarterly summary reports brochures, and PowerPoint presentations. Annual reports were completed for a number of years as part of a TxDOT-sponsored research project. Currently, quarterly summary reports are published through a METRO-sponsored project.

Northern Virginia

A detailed before-and assessment was conducted on the Shirley Highway (I-395) HOV demonstration project starting in 1969. In the mid-1990s the Metropolitan Washington Council of Governments (WASHCOG) initiated an ongoing monitoring, evaluation, and reporting program on HOV lanes in northern Virginia.

Vehicle classification and occupancy counts are conducted by field personnel at selected locations along each corridor. In the fall of 2003, WASHCOG started counting exempt low-emission and energy-efficient vehicles with clean special fuel license plates using the HOV lanes. Additional field personnel record the number of vehicles with the clean special fuel license plates at each of the count stations.

Travel time data are collected using the floating car technique. The travel time runs are conducted in tandem with one vehicle using the HOV lane and one vehicle using the general-purpose freeway lanes. Ridership data on bus and rail services in the different corridors is obtained from the public transportation agencies and private operators.

WASHCOG publishes annual reports on the HOV monitoring program. Key data on average automobile occupancy and travel time savings are presented and described. Trend lines are discussed and changes from the previous year are noted. The count data is provided in 30-minute increments for each location in an appendix.

Puget Sound Region

A monitoring program has been conducted on HOV facilities in the Puget Sound Region since the opening of the I-5 HOV lane in 1983. The monitoring, analysis, and reporting process represents the coordinated efforts of the Washington State Department of Transportation (WSDOT), the Washington State Transportation Center (TRAC), transit agencies, and other groups. Many of the data collection techniques have progressed from manual methods to the use of electronic sensors and other advanced technologies as part of the FLOW system. The presentation of information from the monitoring program has also evolved from printed reports to extensive use of the Internet, including providing access to different databases.

The FLOW system is a coordinated network of traffic monitoring, measuring, information dissemination, and control devices operated on the Interstate and urban state highways in the region. Monitoring and measuring elements include closed-circuit television (CCTV) and electronic sensors. Information dissemination techniques include variable message signs (VMS), highway advisory radio (HAR), and the WSDOT Internet site. Control devices include HOV lanes and meters at selected freeway entrance ramps.

The HOV lane monitoring program focuses on four main elements. These elements are vehicle volumes in the HOV and general-purpose freeway lanes, vehicle-occupancy levels, bus ridership, and travel times in the HOV lanes and general-purpose freeway lanes. Enforcement levels and violation rates, and user and non-user attitudes are also monitored. Procedures for acquiring vehicle volume data from the FLOW system, performing analyses, and presenting outputs have been developed and documented by TRAC. In addition, analysis procedures for calculating AVO, speed, and travel time have been developed and documented.

A variety of methods have been used to present the results from the ongoing HOV monitoring program. These methods include technical reports, summary reports and brochures, and Internet sites. For many years technical reports were published annually documenting the performance of the HOV lanes, including the results of user and non-user surveys. Summary reports and brochures have also been used over the years to present key findings from the HOV performance monitoring program. These documents use graphics to highlight different performance measures. Information on the HOV lanes is available on the WSDOT Internet site. The use of Internet-based publishing of key statistics is increasing. In addition, TRAC provides automobile-occupancy data on one Internet site. Another TRAC Internet site, TRACMap, allows users to link to available databases for specific freeway segments. Users can either access prepared summary statistics or extract specific data.

Los Angeles

An extensive evaluation was conducted on the El Monte Busway, which was opened in 1973. As other HOV lanes were implemented in Los Angeles, they were included in the ongoing monitoring efforts by the California Department of Transportation (Caltrans).

The Los Angeles County Metropolitan Transportation Authority (LAMTA) initiated an HOV performance program study in 2000. The project built on the previous HOV evaluation efforts in southern California and the ongoing monitoring activities conducted by Caltrans. The study was conducted to develop a comprehensive monitoring and evaluation program for the HOV system in the county. The program established a framework for the regular review, evaluation, and reporting on the performance of HOV lanes in the county.

The scope of the study included 16 HOV lane segments in 13 of the 14 freeway corridors with HOV lanes. The study also examined five future HOV segments on four freeways. Finally, two freeways not programmed for future HOV lanes were included as control corridors. A total of 23 freeway segments were included in the project.

The project represented the coordinated efforts of agencies in Los Angeles. The MTA was the lead agency, with support and involvement from Caltrans District 7 and Caltrans Headquarters. A Project Advisory Committee (PAC), composed of representatives from other agencies, helped guide the study.

The first step in the study was to develop a performance monitoring and evaluation plan, including the objectives to guide the performance of the HOV facilities. Measures of effectiveness were identified for each the five objectives. A data collection and analysis program was outlined and conducted to provide the information needed to assess the measures of effectiveness. That data needed for the performance program was obtained from existing sources, and additional data collection activities were conducted.

Vehicle volume information was obtained from the Caltrans District 7 Traffic Monitoring Group (TAG) loop data. Caltrans District 7 staff performed travel time runs – called tachometer (tach) runs because the travel time and delay data are recorded automatically from the vehicle tachometer – in the HOV lanes and the general-purpose freeway lanes.

A number of surveys and other market research activities were conducted as part of the performance program. These activities included three focus groups and 13 interviews with key elected officials, private sector transportation providers, and transit agency representatives. A mail out/mail back survey was distributed to the owners of vehicles observed using the HOV lanes, the general-purpose freeway lanes, and freeways without HOV lanes. A telephone survey was conducted to obtain the perspective of the general public toward the HOV lanes. An on-board survey was conducted of passengers on buses operating in the HOV lanes.

Data from the Caltrans District 7 Traffic Accident Surveillance and Analysis System (TASAS) was used to assess crashes associated with the HOV facilities. The economic viability of the existing HOV lanes were examined using a modified version of the Cal-B/C Model, which is the standard for evaluating transportation projects in California.

A variety of methods were used to present the results of the activities conducted as part of the performance monitoring program. First, periodic newsletters were developed and distributed to members of the PAC, agency personnel, and policy makers. Second, technical memoranda were prepared on the various tasks. Third, a detailed final report was developed, which the presented data collection and analysis methods, and the analysis of the measures of effectiveness. An executive summary, *Eleven Things You Should Know about Carpool Lanes in Los Angeles County*, was prepared and widely distributed to agency management personnel, policy makers, and other groups. PowerPoint presentations have also been given at national conferences highlighting the performance program.

Minneapolis

The I-394 case study provides an example of an extensive before-and-after evaluation, an ongoing monitoring program, and a HOT project assessment. An extensive before-and-after study of the interim and the final HOV lanes was initiated prior to the opening of the interim facility in 1985. The I-394 evaluation program was supported by an ongoing data collection effort. The program included regular vehicle and occupancy counts on the HOV lane, mainlanes, and parallel facilities, travel time runs, accident data, violation rates, surveys of users and non-users, and evaluation of the different marketing and public information programs.

Mn/DOT collects and analyzes key data for the I-394 HOV lanes and the concurrent flow HOV lanes on I-35W on a quarterly basis. Information on the number of vehicles moved in the HOV lane, the general-purpose freeway lanes, and the total facility is presented. The percentage of total person movement, the average automobile-occupancy rate, and the average bus-occupancy rate are also provided. Historical data for the previous four quarters is presented to highlight trend lines and changes in use levels.

The MnPASS HOT project was implemented in May 2005. A comprehensive evaluation is being conducted on the MnPASS project. The evaluation includes two separate, but coordinated elements; an assessment of the system performance and an assessment of user and non-user attitudes. The system performance component focuses on assessing the impact of the project on the operation of I-394. Speed, travel time, trip time reliability, system throughput, safety, enforcement, and roadway operations are being examined. The reliability and efficiency of the MnPASS toll components are also being evaluated. The attitudinal component is monitoring changes in travel behavior and attitudes associated with the MnPASS project.

San Diego

The I-15 Express Lane in San Diego provides an example of a HOT project evaluation. The initial demonstration project and the ongoing HOT project represent the joint efforts of the San Diego Council of Governments (SANDAG), Caltrans, the Metropolitan Transit Development Board (MTDB), and the California Highway Patrol (CHP). The following elements represent examples of the current data collection and analysis activities.

The FasTrack™ Customer Service Center maintains monthly summaries of FasTrack™ account activity. Items tracked include FasTrack application requests, complaints/comments, and account maintenance. Data on vehicle volumes on the I-15 Express Lanes are obtained through inductive loops. The weekday daily average for all vehicles and for HOVs, FasTrak™ vehicles, and tags with invalid reads are summarized on a monthly basis. FasTrak™ records daily toll revenues. CHP maintains a monthly log of the enforcement levels – hours allotted and hours worked by officers in patrol cars and motorcycles – and the number of citations and verbal warnings issued.

In the fall of 1997, a telephone survey was conducted of 1,500 commuters in the San Diego area to obtain information on travel modes, perceptions about the I-15 HOV lane, and the ExpressPass program. A total of 500 ExpressPass customers were included in the survey. In January 2005, SANDAG mailed a survey to 18,000 FasTrak™ customers. The survey contained three questions relating to use of the FasTrak™ Customer Service Center. Other elements of the ongoing assessments include monitoring the use of park-and-ride lots, monitoring bus ridership levels, and an attitudinal panel survey.

CHAPTER THREE – DEVELOPING HOV PERFORMANCE MONITORING PROGRAMS

Chapter-at-a-Glance

This chapter provides background information on the development of HOV performance monitoring programs. It summarizes the federal interest in monitoring and evaluating HOV facilities. The chapter describes the uses and benefits of HOV performance monitoring, evaluation, and reporting programs and the agencies typically involved in these efforts Coordinating with statewide and metropolitan transportation plans in the development of HOV-related goals and objectives is discussed. The steps involved in developing and conducting HOV performance programs are presented. The chapter contains the following sections:

- **Federal Interest in Monitoring and Evaluating HOV Facilities**. This section highlights federal interest and guidance relating to HOV performance monitoring.
- **Uses and Benefits of HOV Performance Monitoring Programs**. This section summarizes the potential uses of HOV performance monitoring programs and the benefits of these activities.
- **Transportation Plans and HOV Systems**. This section highlights the metropolitan and state transportation planning processes and how goals and objectives related to HOV systems fit within these processes.
- **Agencies Involved in HOV Performance Monitoring Programs**. This section describes the agencies typically involved in various aspects of monitoring, evaluating, and reporting on the performance of HOV facilities. The responsibilities of these agencies, including state departments of transportation, transit agencies, MPOs, local jurisdictions, and law enforcement are highlighted.
- **HOV Performance Monitoring Process**. This section describes the steps involved in developing and conducting an HOV performance monitoring program.

Federal Interest in Monitoring and Evaluating HOV Facilities

Federal funding is typically used to support the design, right-of-way acquisition, construction, and operation of freeway HOV lanes. The FHWA Program Guidance on HOV Operations is intended to help protect the federal investment in these facilities and to promote the efficient use of HOV lanes while maintaining the intent of maximizing the person-movement capacity of these facilities. The development and use of HOV performance monitoring programs is strongly encouraged to help ensure the efficient use of these facilities.

The Program Guidance identifies the circumstances under which federal action is required to initiate changes in the operation of an HOV facility, and the federal review process and requirements to be used in these situations. It also provides information on the HOV-related provisions of SAFETEA-LU. The Program Guidance and other recent information on federal activities related to HOV facilities are available on the FHWA Internet site at http://www.fhwa.dot.gov/legsregs/directives/policy/index.htm.

> FHWA provides periodic HOV Program Guidance to support the federal investment in freeway HOV facilities and to help promote their effective use, while maintaining the intent of maximizing the person-movement capacity. The Guidance supports performance monitoring programs, which provide the information needed to make sound decisions on operating HOV facilities.

As noted in the Program Guidance, the source of federal funds used on an HOV project will influence the ability to make changes in the operation of an HOV facility. Some funding categories cannot be used for additional general-purpose roadway capacity. These categories include the Congestion Mitigation and Air Quality (CMAQ) program, the Interstate Maintenance Program, and Mass Transit Capital Investment Grants. Other federal funding sources may have requirements that limit consideration of possible changes in user groups or operating strategies.

Federal action is required when significant changes are proposed to existing HOV facilities constructed with federal funds. Significant changes include major alterations in operating hours and converting an HOV lane to general purpose use. Minor modifications in operating hours and changing from different multi-person occupancy levels (from 3+ to 2+, for example) do not require federal approval. Coordination and consultation with FHWA is appropriate even when an operational change is only being considered or discussed, however, as a basis to determine what may be needed for actual changes to occur.

The Program Guidance identifies the information to be included as part of a federal review. Examples of needed information include original studies and plans for the HOV facility, project agreements, commitments made in the environmental process, operational assessments, analysis of future conditions, examination of alternative operating scenarios, and possible impacts on air quality levels and plans. The Program Guidance further outlines the federal review requirements related to air quality conformity, the state implementation plan, the congestion management system, the National Environmental Policy Act (NEPA) process, and other issues.

SAFETEA-LU contains a number of provisions related to HOV lanes. These provisions include requirements for monitoring, evaluating, and reporting on the use of HOV lanes by certain exempt vehicles. The basic elements of the SAFETEA-LU association with monitoring the performance of HOV lanes are highlighted next. More information on these provisions and requirements is available in the updated FHWA HOV Program Guidance.

- The state agency responsible for operating an HOV lane has authority to establish vehicle-occupancy requirements. No fewer than two occupants per vehicle may be required with the possible exception of the exempt vehicles described next.
- Motorcycles and bicycles shall be allowed to use HOV lanes unless a state agency certifies to the Secretary of Transportation that such use would create a safety hazard and the Secretary accepts the certification.
- Public transportation vehicles with only the driver may be allowed to use an HOV lane if the state agency establishes requirements for clearly identifying these vehicles and procedures for enforcing their use.
- HOT projects are allowed if the state agency establishes a program that addresses how individuals can enroll and participate, uses automatic toll collection, and establishes policies and procedures to manage demand by varying the toll and to enforce violations.
- The state agency may allow low-emission and energy-efficient vehicles, including inherently low-emission vehicles (ILEVs) and other vehicles defined by the U.S. Environmental Protection Agency (EPA), to use HOV lanes without meeting occupancy requirements until September 30, 2009. The state agency must develop and maintain a program to select these vehicles and to enforce their use of HOV lanes.
- A state agency allowing HOT vehicles and/or low-emission and energy-efficient vehicles must establish and maintain a performance monitoring, evaluation, and reporting program.
- The state agency must also establish and maintain an enforcement program to ensure the HOV lane is operated in accordance with federal requirements.
- The state agency is required to limit or discontinue use of the HOV lane by the exempt vehicles if allowing access has degraded the operation of the HOV lane. The operation of an HOV lane is defined as being degraded if vehicles using the facility fail to maintain a minimum average operating speed 90 percent of the time over a consecutive 180-day period during the morning or evening weekday peak-hour periods. The minimum operating speeds are defined as 45 mph when the posted speed limit is 50 mph or

greater and not more than 10 mph below a posted speed limit of less than 50 mph.

Uses and Benefits of HOV Performance Monitoring Programs

HOV performance monitoring, evaluation, and reporting programs provide numerous benefits. Information from HOV performance monitoring programs supports the ability to determine if project goals and objectives are being achieved. Monitoring programs provide information needed to make operating decisions, including changes in vehicle-occupancy requirements and hours of operation. Communicating the use and benefits of HOV facilities to the public and to policy makers is also important. Information from HOV monitoring programs is also of use in planning future projects.

The results of HOV project evaluations are of interest to a variety of individuals and groups. These groups include staff at local, state, and federal agencies; decision makers; special interest groups; the media; and the general public.

Multiple benefits may be realized from HOV performance monitoring, evaluation, and reporting. Performance information supports the ability to determine if the goals and objectives of a project are being achieved. Performance monitoring also provides information needed to make operating decisions, including changes in the operation of an HOV facility.

HOV performance monitoring and evaluation identifies the benefits accrued from a project and helps determine if the goals and objectives of a project are being met. HOV performance monitoring provides an opportunity to ascertain the degree to which the desired results are, in fact, occurring. Ongoing evaluation studies provide an official database for a project. This information can help ensure that all groups are utilizing the same data, assisting to clarify any possible disagreements over the impact of a project.

The information collected as part of an HOV performance monitoring program has value for operating decisions relating to the HOV facility. Information on usage, violation rates, and crashes is critical for ensuring the efficient and safe operation of a facility. Monitoring these and other aspects of an HOV facility helps identify problems that may need to be addressed. For example, changes in operating hours, vehicle occupancy requirements, bus service levels, and access points may be necessary. Longitudinal data on the use of a facility serves a critical operations function. This information can also be used to evaluate the marketing and public information programs associated with a facility, as well as helping to identify if additional marketing is needed.

The results of HOV performance monitoring programs are beneficial in future planning efforts within a metropolitan area. Information from performance monitoring programs can be used to calibrate planning and simulation models for future use. Calibrating models with the results of local evaluations help ensure that they more accurately reflect actual experience, provide a valuable check on the modeling process, and improve the future capabilities of the models. The results from HOV performance monitoring programs, along with the experience gained from a project, can enhance the decision-making process on future projects.

Evaluations may also be needed to meet federal or state requirements. A variety of funding sources may be used to plan, design, construct, and operate various components of an HOV facility. Different funding sources and programs may require ongoing performance monitoring and evaluations or other documentation of project results. Even when not a requirement, HOV project performance monitoring can be useful to help justify future funding for similar facilities in an area.

Finally, by providing information on projects throughout the country, the results of performance monitoring and evaluation efforts create a national database on HOV facilities. Building and maintaining a common body of knowledge on the use and effectiveness of HOV facilities assists transportation professionals and decision makers in keeping pace with critical issues.

Monitoring and evaluating HOV facilities should be coordinated with monitoring and evaluation programs associated with other elements of the transportation system. Ongoing performance monitoring programs may include freeway operations, transportation management centers, incident response activities, and public transportation services. In many cases, the data needed for HOV performance monitoring programs may be available from these and other sources or data collection efforts may be coordinated to maximize available resources.

It is important that the performance monitoring program cover all elements of the HOV facility. Depending on the specific project, these might include HOV lanes, direct access connections, park-and-ride and park-and-pool lots, transit stations, and new or enhanced transit services. In some instances it may be difficult to separate the impact of the various components. The performance monitoring program should be designed to examine the individual components and the full HOV system.

Transportation Plans and HOV Systems

The development and use of an HOV performance monitoring program should be coordinated with related efforts of the state department of transportation, the MPO, the public transportation agency, and other appropriate agencies and groups in a metropolitan area. The development of goals and objectives related to the HOV system should be guided by the missions, goals, and objectives of these agencies and the goals and objectives outlined in the appropriate transportation and transit plans. These plans include the long-range statewide and metropolitan transportation plans required by federal law, long-range and short-range public transportation plans, regional plans, and corridor or facility-specific plans.

These documents outline the goals and objectives of the various agencies responsible for planning and operating different elements of the transportation system. These plans often contain policies relating to HOV facilities. As illustrated in Figure 3.1, these plans should be used as guidance in developing HOV goals and objectives for the HOV performance monitoring program. The following case studies highlight examples of state and metropolitan goals and objectives related to HOV facilities.

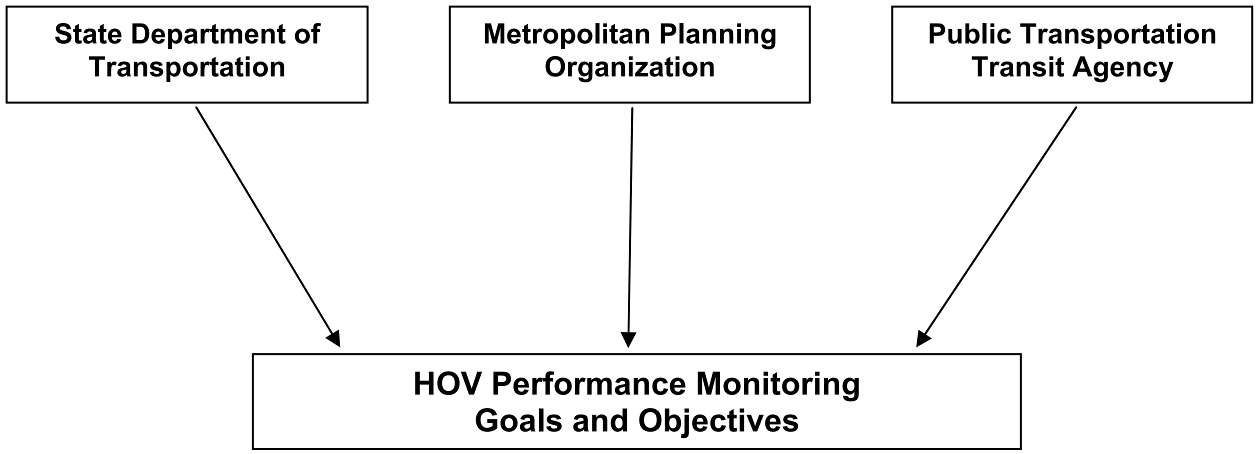


Figure 3.1. Relationship of HOV Performance Monitoring Goals and Objectives to State and Metropolitan Goals and Objectives.

California Department of Transportation

The California Department of Transportation (Caltrans) objectives related to properly designed, freeflowing HOV lanes include the following:

- Increase the people-moving capacity of the freeway system. Reduce overall vehicular congestion and motorist delay by encouraging greater HOV use.
- Provide time and commute costs savings to the users of HOV lanes.
- Increase overall efficiency of the system by allowing HOVs to bypass congestion on lanes designed for their use.
- Improve air quality by decreasing vehicular emissions.

Los Angeles Metropolitan Transportation Authority

The Los Angeles Metropolitan Transportation Authority (MTA) vision and mission statement provides overall guidance on the county transportation system and the 1995 HOV Integration Plan outlines the purpose of HOV facilities in the county.

MTA Vision for Year 2020
Our region will offer a better quality of life where all people can travel quickly, economically, and safely in a clean environment.

MTA Mission Statement
To provide the leadership and resources for a safe, efficient transportation system that keeps Los Angeles County moving. A better tomorrow rides on us.

MTA 1995 HOV Integration Plan
The purpose of the HOV system in Los Angeles County is to enhance mobility for all county residents by providing a system of dedicated lanes that serves to both encourage use of transit and carpools, as well as support other county-wide objectives of improving air quality, trip reduction, and efficient movement of persons and goods.

Washington State Department of Transportation

The *Washington State Freeway HOV System Policy* outlines 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 versus outside) and separation, general-purpose lane conversion, HOV system performance, promotion, design standards, land use coordination, and supporting programs, services, and facilities. It is one of the more comprehensive sets of HOV policies currently in use. The policies were developed by a multi-agency stakeholder group and adopted by senior management and the Transportation Commission.

Metropolitan Council of the Twin Cities Area

Goals and policies related to HOV facilities in the Minneapolis-St. Paul metropolitan area are included in a number of documents developed and adopted by the Metropolitan Council. These include the *Transportation Development Guide/Policy Plan* and the *Regional Transit Facilities Plan*. The philosophy presented in the *Transportation Guide* recognizes that the region cannot meet growing demand by simply adding new roads and services. Support for HOV facilities and other related elements are contained in the philosophy and in specific goals and policies. The vision presented in the *Transit Facilities Plan* focuses on four major elements. These are strong transportation management, incentives for HOV use, strengthened transit services, and more efficient and transit friendly land uses. Specific corridors where HOV facilities and supporting services should be considered are highlighted.

Agencies Involved in HOV Performance Monitoring Programs

The agencies typically involved with HOV performance monitoring, evaluation, and reporting include state departments of transportation, public transportation agencies, MPOs, and state and local law enforcement agencies. Depending on the type of HOV facility, cities and counties may also participate. Representatives from FHWA and the Federal Transit Administration (FTA) are frequently involved. Table 3.1 identifies the common roles and responsibilities of each group, including those related to HOV performance monitoring programs. In addition, representatives from rideshare agencies, regional organizations, and the judicial system may participate in multi-agency teams and may assist with HOV performance monitoring activities.

Federal Government and Agencies. The federal government is responsible for establishing national transportation policies, programs, and funding levels. The Congress and the President are responsible for authorizing legislation, which is administered by the federal agencies. Currently, SAFETEA-LU provides the overall direction for the transportation system, establishes specific programs, and authorizes funding levels.

A key to the success of many HOV projects, including HOV performance monitoring programs, is the involvement of personnel from all appropriate agencies and groups. Multi-agency teams are often used in planning, designing, implementing, operating, and monitoring HOV facilities. Using multi-agency teams in developing and conducting HOV performance monitoring programs helps ensure that the objectives and measures of effectiveness focus on key project goals, that the appropriate data collection and analysis techniques are used, and that the results are provided to key groups Multi-agency teams can also facilitate shared funding and data collection responsibilities for HOV

SAFETEA-LU and other Acts provide policy level guidance related to HOV facilities, as well as establishing specific program requirements. FHWA and FTA are the two modal agencies within the U.S. Department of Transportation with responsibilities for HOV facilities. These responsibilities include developing specific rules and program guidelines in response to legislative directives, reviewing plans and designs, approving project funding, and providing technical assistance. As noted previously, the FHWA Program Guidance on HOV Operations provides direction on monitoring the performance of HOV facilities.

State Government and State Transportation Agencies. State governments have responsibility for the Interstate highway system within their borders and state-owned transportation facilities. State governments establish the programs, funding mechanisms, and policies related to the various components of the state transportation system. For example, the legislative or executive branch may establish financing methods such as a state gasoline tax or other taxes and fees, adopt policies relating to the types of facilities and services that will be provided by the state, and authorize state agencies to carry out specific responsibilities related to planning, designing, constructing, and operating various transportation elements. States also have responsibilities in a number of areas that may influence the transportation system. These include land use and growth control regulations, trip reduction requirements, and other related programs.

The state department of transportation or highway department is the agency typically charged with planning, designing, constructing, operating, and maintaining the Interstate system and the state-owned roadway system. A state transportation agency will typically have the lead responsibility for HOV facilities on freeways and state-owned roadways. On these projects, the state department of transportation typically is the lead agency with HOV performance monitoring programs. These agencies often play important supporting roles with projects in separate rights-of-way and on local arterial streets. In many areas, state departments of transportation have been responsible for organizing, staffing, and chairing the multi-agency project management team associated with an HOV project, including performance monitoring.

Metropolitan Planning Organizations (MPOs). MPOs were created in 1964 by federal legislation to coordinate the transportation planning process and the project selection process in urban areas. MPOs were charged with conducting the "3C" (Continuous, Cooperative, and Coordinated) transportation planning process in these areas. The roles and responsibilities of MPOs have been modified over the years. Further, some MPOs have been given additional authority based on state legislation.

Table 3.1. Roles and Responsibilities of Federal, State, and Local Governments and Agencies Related to HOV Performance Monitoring.

Government Level or Agency	Potential Roles and Responsibility
Federal Government and Federal Agencies	X Establish national transportation policies. X Establish programs and requirements. X Authorize and appropriate funding. X FHWA and FTA responsible for administering programs and funding and establishing monitoring and reporting guidelines. X May participate in multi-agency HOV project teams, including performance monitoring.
State Government and State Transportation Agencies	X Establish state transportation policies, plans and programs. X Authorize and appropriate state funds and the expenditure of federal funds. X State transportation agency responsible for administering programs and funding. X Plan, design, construct, operate, and maintain Interstate system and state-owned roadways, including HOV facilities. X Frequently lead agency on HOV performance monitoring programs, including heading multi-agency team, data collection, and reporting.
Metropolitan Planning Organizations (MPOs)	X Conduct "3-C" planning process. X Develop and adopt plans and policies. X Conduct project selection process. X May provide funding for HOV performance monitoring programs; assist with data collection, analysis, and reporting; and participate in multi-agency team.
Public Transportation Agencies	X Establish plans and policies for public transportation. X Receive federal and state funds for transit. X Construct, develop, and operate transit services, including BRT and bus-only projects. X Lead on monitoring BRT and bus-only projects. X Assist with data collection and analysis, and serve on multi-agency teams.
Counties and Cities	X Establish local policies and plans. X Plan, design, construct, and operate local roadway and traffic signal system and other elements, including HOV facilities. X Lead on arterial street and support on freeway HOV performance monitoring programs.
State and Local Law Enforcement Agencies	X Enforce laws on roadways and other transportation elements, including HOV facilities. X Coordination with judicial personnel. X Provide input on planning, operation, and enforcement of HOV facilities. X Provide data on crashes and enforcement on HOV facilities and participate on multi-agency teams.

In general, MPOs are responsible for developing and adopting the long-range transportation plan, the short-range transportation improvement program (TIP), other policies and plans, and conducting the public involvement process. The policy boards of MPOs are comprised of local elected officials and appointed representatives. MPOs also utilize an advisory committee structure involving policy makers, technical staff from other agencies and jurisdictions, and the public. Representatives from an MPO are usually members of multi-agency planning groups associated with HOV facilities. Staff from the MPO may help facilitate meetings or implementation strategies, as well as assist with multi-agency coordination and the public involvement process. The policies, goals, and objectives included in the transportation plans completed by MPOs usually address HOV facilities. MPOs may help fund HOV performance monitoring programs and may conduct some data collection, analysis, and reporting activities.

Public Transportation Agencies. Most metropolitan regions, smaller communities, and rural areas are served by some type of public transportation system. The exact agency or organizational structure may take a variety of forms and may provide a range of services. Regional transit agencies have been created in most large metropolitan regions throughout the country based on some combination of state legislation, authorization from local jurisdictions, and voter approval. These agencies are responsible for planning, designing, implementing, and operating transit modes which may include paratransit, local and express fixed route, light rail transit (LRT), BRT, heavy rail, commuter rail, people movers, and carpool and vanpool services. Public transit agencies may finance these services and accompanying fixed facilities through a combination of federal, state, and local funds, and revenues from users. Transit agencies often have the lead responsibility with HOV facilities in separate rights-of-way, including BRT, and may be a co-sponsor or play a supporting role with HOV projects on freeways and arterial streets. Some, transit agencies are responsible for enforcing vehicle eligibility, vehicle-occupancy, and other requirements associated with HOV facilities. Public transportation agencies typically provide data related to bus volumes, passenger levels, bus travel times, and other related activities associated with HOV performance monitoring programs.

Cities and Counties. Cities and counties are responsible for local roadways and other local components of the transportation system. As a result, these jurisdictions have authority over planning, designing, funding, implementing, and operating the local street and traffic signal systems. Local jurisdictions have authority for land use and development controls, including zoning, site design, and subdivision regulations. Local governments thus play an important role in coordinating land use and transportation planning and development. Local municipalities usually have the lead responsibility on arterial street HOV applications and often have important supporting roles with HOV facilities on freeways and in separate rights-of-way. Local municipalities may have policies and plans relating to HOV facilities. Local governments typically play a lead role on arterial street HOV performance monitoring and a support role in monitoring and evaluating freeway HOV facilities.

State and Local Law Enforcement Agencies. State and local law enforcement officials are responsible for upholding the laws and regulations related to the safe operation of roadways and other elements of the transportation system. Although the fines and other penalties imposed on violators are determined by state legislation and local laws, the police are responsible for enforcing these regulations. Involving law enforcement personnel throughout all aspects of planning, designing, constructing, implementing, and operating HOV facilities is important to ensure that the completed projects can be safely and efficiently enforced. Experience indicates that including state, local, and transit police throughout all phases of the development process is critical to the success of an HOV project. In monitoring the performance of an HOV facility, law enforcement officials may participate in multi-agency teams and provide specific information. State and local police typically maintain crash records and data on HOV-related citations.

In addition to these agencies, regional rideshare agencies and transportation management organizations or other regional groups may participate in and support HOV-related programs, including performance monitoring programs. Finally, the judicial system may provide needed data on HOV fines and citations.

Rideshare Agency. In many metropolitan areas, the transit agency operates not only bus or rail services, but also provides ridematching services, vanpool programs, and other ridesharing services. In some areas, however, these activities are the responsibility of a separate agency or organization. In these cases, the rideshare agency typically participates in the metropolitan transportation planning process, adopts policies relating to HOVs, and provides technical assistance and services to public agencies, private businesses, and other groups. Representatives from rideshare agencies may participate in HOV multi-agency teams. Rideshare agencies may maintain and provide data on carpool matches, the number of vanpools, and other related programs, which is used in HOV performance monitoring programs.

Transportation Management Organizations (TMOs), Transportation Management Associations (TMAs), Downtown Councils, and Other Regional Groups. These types of voluntary organizations, which are usually composed of major employers in an area, often promote specific transportation improvements, help facilitate programs and activities among members, and may assist in funding projects. They can also help promote the use of an HOV facility or other program among their employees. These organizations may participate on HOV project teams and may provide information related to some elements in an HOV performance monitoring program.

Judicial System. The federal, state, and local court systems are responsible for determining the validity of any appeal on the constitutionality of enforcement techniques, fines, or other legal issues. Ensuring that the fines and citations issued by enforcement personnel are handled appropriately in the local or state court system is an important aspect to the success of HOV facilities. Data on fines and HOV-related citations are typically obtained through the judicial system.

HOV Performance Monitoring Process

This section describes the HOV performance monitoring process. The development of an HOV performance monitoring program should include the major activities that would normally be conducted as part of any evaluation program. The major steps in this process are illustrated in Figure 3.2 and briefly outlined next. To ensure that a comprehensive, well-designed performance monitoring program is pursued, consideration should be given to each of these steps.

Ensuring that the HOV project objectives are well thought out and articulated is a key part of HOV performance monitoring programs. Objectives should flow from the broader project goals, and should be well defined and measurable statements.

NCHRP Report 446, *Multimodal Transportation: Development of a Performance-Based Transportation Planning Process,* and the soon to be available NCHRP 8-36, *Guide to Effective Freeway Performance Measurement*, provide additional information on performance monitoring programs. Appendix A contains information on these reports and other technical documents that may be of use with HOV performance monitoring programs.

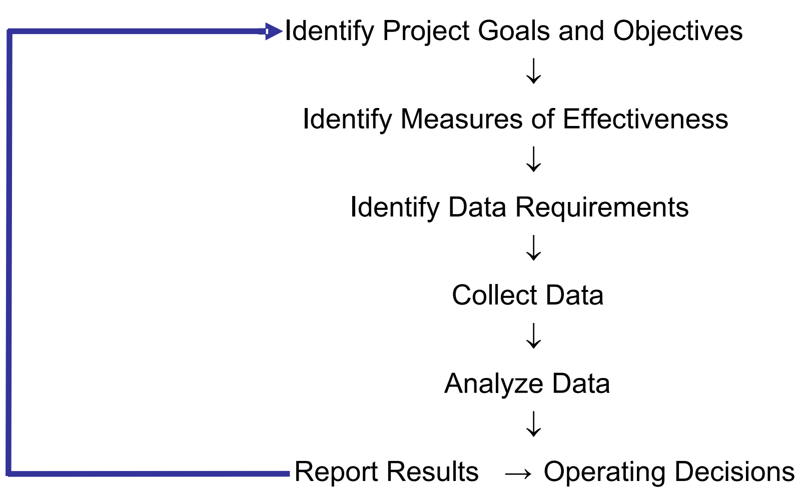


Figure 3.2. Steps in Developing and Conducting an HOV Performance Monitoring Program.

Identification of Project Goals and Objectives. The goals and objectives that an HOV project are intended to accomplish should be clearly defined as the first step in developing a performance monitoring program. These goals and objectives should flow from, and be consistent with, those articulated during the policy development phase and the planning process. This step is critical, as the remainder of the performance monitoring program will be designed to obtain and evaluate information that will be used to determine if these objectives have been met. The development of measurable objectives is not an easy task, but time spent on this effort will help ensure a focused monitoring program.

The objectives of an HOV project should be stated clearly and concisely. Each objective should represent a well-defined and measurable statement. A commonly used approach in developing measurable objective statements is to ensure that the statement includes the desired end result, the action that will be taken to achieve this result, and the time frame within which the result will occur.

Identify Measures of Effectiveness. For each objective, the appropriate measure or measures of effectiveness should be identified. The desired threshold level of change that will be used to determine if the facility has met the objective should also be identified. It is important that this activity focus on identifying the measures that most accurately relate to the objectives, and that meaningful threshold levels are established. These measures and thresholds should relate to the key elements in the objective statements.

Identify Data Requirements. This step identifies the data needed for the performance monitoring process. The data needs for each measure of effectiveness should be outlined, and the appropriate methods to obtain and evaluate the information must be identified. Ideally, the same procedures and definitions should be used throughout the performance monitoring program to ensure comparability. Any changes in data collection procedures, such as those associated with implementing advanced technologies, or definitions should be well documented.

Collect Data. In this step the data identified in the previous step is collected. As described in Chapter Four, a variety of data collection techniques are typically associated with HOV performance monitoring programs. Data collection techniques may include observation of vehicle volumes and vehicle-occupancy levels, using information from advanced transportation management systems (ATMS), and reviewing crash data and occupancy or buffer violation citations.

Analyze Data. In this step the data collected in the previous step is analyzed to provide usable information. The information is then examined to determine if the measures of effectiveness have been met. Chapter Four describes the analysis techniques typically used with HOV performance monitoring programs, as well as some of the issues that may be encountered in analyzing HOV data.

Report Results. The results from HOV performance monitoring programs may be used for numerous purposes by different audiences. The results are typically used to determine if the project goals and objectives are being met. Information from performance monitoring programs is also used to make decisions concerning operation of an HOV facility. As described in Chapter Six, a variety of methods are typically used to report the results to different audiences and stakeholder groups.

Following this general approach will result in the development, implementation, and conduct of a meaningful HOV performance monitoring program. While some elements of this approach may vary in different areas, the basic procedures are appropriate for consideration in monitoring and evaluating all types of HOV facilities.

CHAPTER FOUR – HOV SYSTEM OBJECTIVES, MEASURES OF EFFECTIVENESS, AND DATA REQIREMENTS

Chapter-at-a-Glance

This chapter presents common objectives for HOV facilities throughout the country and related measures of effectiveness. The data requirements associated with these measures of effectiveness are also identified. The chapter contains the following sections:

- **HOV Objectives and Measures of Effectiveness**. The objectives and measures of effectiveness frequently associated with HOV facilities are discussed in this section. Examples of objectives and measures of effectiveness used with current HOV performance monitoring programs are presented. Potential objectives associated with HOT projects are also presented, along with case study examples.
- **Data Requirements**. This section highlights the data requirements associated with the measures of effectiveness outlined in the previous section.

HOV Objectives and Measures of Effectiveness

As discussed in the previous chapter, the first step in the development of an HOV performance monitoring program is to ensure that there is agreement on the project goals and objectives. It is important to ensure that the objectives are measurable, as the remainder of the evaluation program will focus on gathering and analyzing information to determine if the objectives have been met.

After the objectives have been clearly defined, the next step is to identify the appropriate measures of effectiveness or evaluation criteria that correspond to each objective. These measures should focus on the key elements of the objectives, so that the information needed to determine if the objective has been achieved can be collected and analyzed.

The following three case studies highlight objectives and measures of effectiveness related to HOV facilities in the U.S. The first case study highlights commonly used objectives identified in an FTA-sponsored study in the early 1990s and updated in the NCHRP *HOV Systems Manual* in the late 1990s. The second case study highlights the objectives for the Washington State freeway system. The third case study outlines the objectives and measures of effectiveness used in the Los Angeles Metropolitan Transportation Authority's HOV performance program study.

National Overview of Typical HOV System Objectives

An FTA-sponsored research project in the early 1990s examined before-and-after studies completed on HOV projects in the U.S. This information was updated during the development of the NCHRP *HOV Systems Manual* in the late 1990s. The following nine objectives were identified as examples of HOV objectives used by different agencies in the country.

- The HOV facility should improve the capability of a congested freeway corridor to move more people by increasing the number of persons per vehicle.
- The HOV facility should increase the operating efficiency of bus service in the freeway corridor.
- The HOV facility should provide travel time savings and a more reliable trip time to high-occupancy vehicles utilizing the facility.
- The HOV facility should not unduly impact the operation of the freeway general-purpose mainlanes.
- The HOV facility should increase the per lane efficiency of the total freeway facility.
- The HOV facility should be safe and should not unduly impact the safety of the freeway general-purpose mainlanes.
- The HOV facility should have public support.
- The HOV facility should be a cost-effective transportation improvement.
- The HOV facility should provide favorable impacts on air quality and energy consumption.

Washington State Freeway HOV System Objectives

The 1992 Washington State Freeway HOV System Policy report outlines the following three objectives for HOV facilities in the state.

- Improve the capacity of congested freeway corridors to move more people by increasing the number of people per vehicle.
- Provide travel time savings and a more reliable trip time to HOVs that use the facilities.
- Provide safe travel options for HOVs without unduly affecting the safety of freeway general-purpose lanes.

Person throughput, vehicle-occupancy, travel time, speed, and reliability represent the primary measures of effectiveness used to determine if these objectives are being met. Secondary performance measures include enforcement and violation rates and public perceptions.

Los Angeles County HOV Performance Program Study Objectives

The Los Angeles County Metropolitan Transportation Authority HOV performance program study established a framework for the ongoing monitoring of HOV lanes in the County. The following five objectives and related measures of effectiveness were identified as part of the study process to help guide the performance monitoring and evaluation plan.

Objective: Manage travel demand by increasing the person movement capacity in congested freeway corridors.
Measures of Effectiveness

- Average Vehicle Occupancy
- Person Trips
- Percent of Persons versus Vehicles
- Carpools and Vanpools
- Buses and Bus Riders

Objective: Encourage carpooling, vanpooling, and bus use by providing travel and mobility options.
Measures of Effectiveness

- Transit Operators Attitudes
- Ridesharing Activities
- System Connections

Objective: Provide travel time savings and trip reliability to HOV lane users.
Measures of Effectiveness

- Travel Time Savings
- Travel Speed

Objective: Provide air quality benefits.
Measures of Effectiveness

- HOV Corridor Vehicles Emissions
- HOV Lane Vehicle Emissions

Objective: Promote a cost-effective transportation system.
Measures of Effectiveness

- Transit Operations
- Benefit-Cost/Benefit-Cost Ratio, Net Present Value, Economic Rate of Return, and Year of Economic Feasibility
- Public Perceptions – Adequate Use
- Public Perceptions – Good Improvement
- Violation Rates

Although the objectives and measures of effectiveness in the case study examples vary in the exact wording, they focus on similar goals and policies related to HOV facilities. The common objectives address person (rather than vehicle) throughput, providing travel time savings and trip time reliability to HOVs, safety, public acceptance, cost-effectiveness, and air quality and energy consumption.

Table 4.1 presents these common objectives and possible related measures of effectiveness. A more detailed discussion of these objectives and measures of effectiveness follows. The data needed to analyze the measures of effectiveness are noted and potential issues associated with obtaining and analyzing the data are described.

This information is provided to assist in the development of objectives and measures of effectiveness for HOV performance monitoring programs. These examples can be tailored to meet the goals and policies of individual areas. The development of objectives and measures of effectiveness will also be influenced by the type of HOV facility, the operating requirements, and whether it is a new or existing facility. As noted in the discussion of the possible measures of effectiveness, consideration should be given to monitoring the performance of a control freeway (a freeway without an HOV lane) to provide a basis for comparison.

Objective: The HOV facility should improve the capability of a congested freeway corridor to move more people by increasing the number of persons per vehicle.

Measures of Effectiveness: In general, the increase in the peak-hour, peak-direction person volume resulting from the HOV facility should at least be greater than the percentage increase in directional lanes added to the roadway. This objective will be accomplished by increasing the average vehicle occupancy on the roadway. A significant portion of the increase in average vehicle occupancy should be the result of creating new carpoolers and new bus riders, rather than just diverting uses, carpools, and vanpools from the adjacent freeway lanes or parallel routes to the HOV facility. The attraction of a significant volume of new bus and carpool users is critical to the effectiveness of HOV facilities. Simply moving existing rideshare patrons from the general-purpose lanes or parallel routes will not impact the person movement capability of the total corridor.

Table 4.1. Typical HOV Objectives and Measures of Effectiveness.

Objective	Measures of Effectiveness
⊄ The HOV facility should improve the capability of a congested freeway corridor to move more people by increasing the number of persons per vehicle.	⊄ Actual and percent increase in the person-movement efficiency. ⊄ Actual and percent increase in average vehicle-occupancy rate. ⊄ Actual and percent increase in carpools and vanpools. ⊄ Actual and percent increase in bus riders.
⊄ The HOV facility should provide travel time savings and a more reliable trip time to HOVs utilizing the facility over vehicles in the general-purpose lanes	⊄ Peak-period, peak-direction travel time in the HOV lane(s) should be less than the adjacent general-purpose freeway lanes. ⊄ Travel time reliability for vehicles using the HOV lane should be better than vehicles in the general-purpose lanes.
⊄ The HOV facility should not unduly impact the operation of the freeway general-purpose lanes.	⊄ The level of service in the freeway general-purpose lanes should not decline due to the HOV lane.
⊄ The HOV facility should be safe and should not unduly impact the safety of the freeway general-purpose lanes.	⊄ Number and severity of crashes for HOV and general-purpose lanes. ⊄ Crash rate per 100 million vehicle miles of travel (VMT). ⊄ Crash rate per million passenger miles of travel.
⊄ The HOV facility should increase the operating efficiency of bus service in the freeway corridor.	⊄ Improvement in vehicle productivity (operating cost per vehicle mile, operating cost per passenger, operating cost per passenger mile). ⊄ Improved bus schedule adherence (on-time performance). ⊄ Improved bus safety (crash rates).
⊄ The HOV facility should have public support or public acceptance.	⊄ Support for the facility among users, non-users, general public, and policy makers. ⊄ Violation rates (percent of vehicles not meeting the occupancy requirement).
⊄ The HOV facility should have favorable impacts on air quality and energy consumption.	⊄ Reduction in the growth of emissions. ⊄ Reduction in the growth of total fuel consumption. ⊄ Reduction in the growth of VMT and vehicle hours of travel (VHT).
⊄ The HOV facility should be a cost-effective transportation improvement.	⊄ Benefit-cost ratio.

The following measures of effectiveness may be appropriate for consideration with this objective. Specific criteria for anticipated changes in the peak hour, peak period, and the daily total may be identified for each measure of effectiveness.

- Actual and percent increase in the person movement on the total freeway facility (general-purpose lanes plus HOV facility).
- Actual and percent increase in the average vehicle occupancy rate for the total freeway facility (general-purpose lanes plus HOV facility).
- Actual and percent increase in carpools and vanpools for the total freeway facility (general-purpose lanes plus HOV facility).
- Actual and percent increase in bus riders for the total freeway facility (general-purpose lanes plus HOV facility).

Data Needs: The primary data needs for these measures of effectiveness include vehicle and vehicle-occupancy counts and bus ridership level on the HOV facility and the general-purpose freeway lanes. Secondary data needs include vehicle and occupancy counts on parallel roadways, and surveys of bus riders, carpoolers, and vanpoolers in the HOV lanes, and non-users in the general-purpose lanes. If a control freeway (without an HOV lane) is being used in the monitoring program, vehicles and vehicle-occupancy counts and bus ridership will be needed for that facility.

Possible Issues: Increasing the capacity of a congested travel corridor is typically a main objective of an HOV facility. The data needed to assess the measures of effectiveness associated with this objective represent the basic elements of a monitoring program. Possible issues to consider relate to collecting data before a new HOV lane is open and using a control freeway in the monitoring program.

Objective: The HOV facility should provide travel time savings and a more reliable trip time to high-occupancy vehicles utilizing the HOV facility over vehicles in the general-purpose lanes.

Measures of Effectiveness: During the peak-periods, the travel time on the HOV facility should be less than the travel time on the adjacent freeway lanes in the peak-direction of travel. The reliability of the travel time in the HOV lane should also improve from that experienced in the general-purpose lanes in the pre-HOV lane period and on an ongoing basis. The travel time index and the buffer index are two measures used by FHWA to examine freeway performance. These indexes are appropriate for use with HOV facilities. The Washington State Department of Transportation (WSDOT) uses a guide that HOV lane vehicles should maintain or exceed an average of 45 mph or greater at least 90 percent of the time they use the lane during the peak hours, measured for a consecutive six-month period. The formulas used to calculate these measures are discussed in Chapter Five.

Data Needs: If the HOV project is new, travel time data on vehicles and speeds in the general-purpose lanes should be collected before the HOV project is implemented. Data on vehicle travel times and speeds in both the HOV lane(s) and the general-purpose freeway lanes should be collected on an ongoing basis after the HOV facility is open. Travel time and speed data is used to measure travel time reliability.

Possible Issues: This objective and the related measures of effectiveness are commonly used with most HOV performance monitoring programs, as the key benefits of an HOV lane are providing travel time savings and trip time reliability. It is important that enough observations be conducted over an adequate number of days to ensure an accurate reflection of travel time reliability.

Objective: The HOV facility should not unduly impact the operation of the freeway general-purpose lanes.

Measures of Effectiveness: The capacity and operating speeds of the adjacent freeway general-purpose lanes should not be degraded due to the implementation of the HOV facility. This can be measured by a comparison of the level-of-service on the general-purpose lanes before and after implementation of the HOV project.

Data Needs: The information obtained from the freeway and HOV lane vehicle and occupancy counts and travel time data taken before and after implementation of the HOV facility are used to calculate the level-of-service.

Possible Issues: This objective relates to the implementation of a new HOV lane. It may not be an appropriate objective for an existing HOV facility, especially as traffic volumes increase in a corridor.

Objective: The HOV facility should be safe and should not unduly impact the safety of the freeway general-purpose lanes.

Measures of Effectiveness: Appropriate measures of effectiveness include a before-and-after comparison of the following items for a new HOV lane and the ongoing monitoring of these elements with an existing HOV lane.

- Number and severity of crashes for HOV and freeway lanes.
- Crash rate per 100 million vehicle miles or million passenger miles of travel for the HOV and freeway lanes.

Data Needs: For a new HOV project, crash data on the freeway general-purpose lanes should be collected for a representative period of time before the HOV facility is opened. Data on the crash rates for both the HOV lane and the general-purpose lanes should then be collected on an ongoing basis after the HOV facility is open. Information collected should include the number, type, and severity of crashes. If a control freeway is being used, the same crash data should be collected for this facility.

Possible Issues: Crash data can be difficult to obtain and to analyze for a number of reasons. As discussed in more detail in Chapter Five, crash data may be collected by a number of different agencies, the data collection and analysis methods may be different, and the crash records may not always be complete.

Objective: The HOV facility should increase the operating efficiency of bus service in the freeway corridor.

Measures of Effectiveness: By increasing bus operating speeds and improving service reliability, HOV facilities can increase the vehicle operating efficiency of bus service in the freeway corridor. HOV lanes also provide operating efficiencies for new bus services versus traveling in the general-purpose lanes. The following measures of effectiveness might be appropriate for use with this objective. Other measures outlined in the FTA Evaluation Guidelines for Bus Rapid Transit Demonstration Projects may be considered.

- Improvement in vehicle productivity, measured by operating cost per vehicle mile, operating cost per passenger, operating cost per passenger mile.
- Improved bus schedule adherence, measured by on-time performance.
- Improved bus safety, measured by a reduction in vehicle accident rates.

Data Needs: Data needed for these measures of effectiveness include before-and-after bus service levels; vehicle productivity; on-time performance; number and severity of bus accidents; vehicle operating costs; and changes in labor, fuel, and other costs. On-time performance is usually measured by the number of vehicles arriving at their destination at the scheduled time. On-time performance may be defined differently by different transit systems, but a range from arriving on schedule to five minutes behind schedule is often used. Monitoring the actual arrival times of buses before-and-after implementation of the HOV facility may be appropriate to provide the most accurate picture of changes in on-time performance. In addition, the perception of bus users can be measured through the use of on-board ridership surveys.

Possible Issues: If no bus service was operated in the corridor prior to the opening of an HOV lane, this objective may not be appropriate or the measures of effectiveness may focus on a comparison of buses operating in the HOV lane and the general-purpose traffic lanes.

Objective: The HOV facility should have public support or public acceptance.

Measures of Effectiveness: Opinion surveys or other techniques should show support or acceptance for the HOV facility among users, non-users, the general public, and policy makers. One measure of effectiveness might focus on the perception of utilization of the HOV facility and another measure of effectiveness might focus on the perception of whether it is a good transportation improvement. The violation rates and compliance with operating requirements on an HOV facility may also be appropriate measures of effectiveness for this objective.

Data Needs: Data needed to evaluate this objective can be obtained from surveys of users and non-users, focus groups, and stakeholder interviews; monitoring of calls, letters, and newspaper articles; violation rates; and enforcement levels. Some of this information can be gathered through ongoing marketing and public information programs, which usually track press coverage, calls, letters, and e-mails.

Possible Issues: Obtaining funding to conduct surveys of users, non-users, and the public may be difficult in some areas. It is also important that the questionnaires are unbiased, that the sample size adequate, and that valid sampling and survey methods are used.

Objective: The HOV facility should be a cost-effective transportation improvement.

Measures of Effectiveness: The measure most commonly used with this objective is the benefit-cost ratio. Other possible measures of effectiveness include net present value, economic rate of return, and year of economic feasibility for the HOV lane.

Data Needs: To develop a benefit-cost ratio, the total cost (capital and operating) of the project is needed along with a costing of the benefits. As discussed above, it is suggested that the travel time savings to persons using the facility be used as a primary benefit.

Possible Issues: It is frequently difficult to obtain cost data on HOV facilities, especially for a facility that has been in operation for many years. Even a new HOV lane may be part of a larger freeway improvement project and determining the cost specifically associated with the HOV portion may be difficult.

Objective: The HOV facility should have favorable impacts on air quality and energy consumption.

Measures of Effectiveness: For the total demand being served by the facility, the HOV facility should have more favorable impacts on air quality and energy consumption than would either no improvement at all or the addition of a general purpose lane. The measures of effectiveness that may be used with this objective are typically based on calculations or simulation models that use information generated from other objectives. The following measures of effectiveness may be appropriate for use with this objective.

- Reductions in the growth of emissions.
- Reductions in the growth in total fuel consumption.
- Reductions in the growth of VMT and VHT.

Data Needs: Estimations based on vehicle and occupancy counts, travel time runs, and responses to surveys are usually used to measure changes in these measures of effectiveness.

Possible Issues: Estimating the potential air quality and energy impacts of an HOV facility are difficult. First, many simulation models require a large amount of data. This data may not always be available. Second, in general, HOV lanes will have a relatively small impact on air quality and energy consumption due to their limited nature.

The objectives and measures of effectiveness presented above relate primarily to HOV facilities open to buses, vanpools, and carpools. If priced vehicles, low-emission and energy-efficient vehicles, or other types of vehicles exempt from the occupancy requirements are allowed to access an HOV facility, objectives and measures of effectiveness should be developed for their use. These vehicles should also be included in the data collection and analysis process.

Objectives associated with HOT components may relate to improving the efficiency of an HOV lane, generating revenue to fund additional transit and highway improvements in the corridor, and introducing or testing ETC or variable pricing. Objectives of the MnPASS project are highlighted in the case study example. Data needed to assess HOT objectives typically include the number of HOT vehicles and HOT violators, the number of accounts opened, and the number of transponders issued. The operator of the toll collection system usually maintains these data.

Data Requirements

The data requirements for the various measures of effectiveness were noted in the previous section. The basic data needs are summarized below and mapped to the different measures of effectiveness in Table 4.2. The techniques for collecting and analyzing these data are presented in Chapter Five.

- Updated HOV facility inventory.
- Vehicle volumes by type of vehicle in the HOV lanes and general-purpose lanes. Type of vehicles may include buses, vanpools, and carpools, and possible use by Inherently Low-Emission Vehicles (ILEVs), hybrid vehicles, value pricing participants, and fully marked law enforcement vehicles.
- Vehicle occupancy counts in the HOV lanes and general-purpose lanes.
- Travel times in the HOV lanes and general-purpose lanes.
- Travel speeds in the HOV lanes and general-purpose lanes.
- Trip time reliability in the HOV lanes and general-purpose lanes.
- Bus ridership levels in the HOV lanes and general-purpose lanes.
- Park-and-ride and park-and-pool lot use.

> The MnPASS project has a number of objectives. The first objective is to improve the efficiency of I-394 by increasing the person-carrying and vehicle-carrying capabilities of the HOV lanes. The second objective is to maintain freeflow speeds for transit and carpools in the HOV lanes. The third objective is to improve highway and transit in the corridor with the revenues generated from the project. The fourth objective is to deploy electronic toll collection, including tags, transponders, and readers to maintain travel speeds. The final objective is to employ new ITS technologies to facilitate dynamic pricing and in-vehicle electronic enforcement.

- Occupancy violations, access violations, pricing violations, and other violations.
- Number and nature of crashes in the HOV lanes and general-purpose lanes.
- Perceptions of users, non-users, the public, and policy makers.
- Measures relating to vehicle emissions and air quality.
- Measures relating to capital and operating costs.

Table 4.2. Data Requirements Mapped to HOV Lane Objectives.

Objective	Data Requirements: Vehicle and Occupancy Counts – Freeway[2]	Vehicle and Occupancy Counts – HOV Lane	Travel Time/Speed – Freeway[2]	Travel Time/Speed – HOV Lane	Surveys[1] – Freeway[2]	Surveys[1] – HOV Lane	Violations/ Citations – HOV Lane	Crash Data – Freeway[2]	Crash Data – HOV Lane	Other
Increase vehicle occupancy	●	●			●●	●●				●●3
Travel time savings/trip time reliability			●	●	●●	●●				●●4
Maintain freeway operations	●		●		●●			●	●	
Safety of HOV and Freeway	●●	●●	●●	●●	●●	●●	●●	●	●	
Bus operating efficiency	●	●	●	●		●		●	●	●5
Public support/acceptance	●●	●●			●	●	●			●●6
Air quality/energy	●	●	●	●	●●	●●				●7
Cost effective	●●	●	●	●						●8

● Indicates the top priority data collection efforts needed to evaluate the objectives.

●● Indicates data collection efforts which should ideally be conducted, but are not absolutely necessary to evaluate the objectives.

1 Includes periodic surveys of HOV users (bus riders, carpoolers, and vanpoolers), non-HOV users in the general traffic lanes, the general public, and stakeholders.
2 It is suggested that these data be collected for both the freeway lanes adjacent to the HOV facility, parallel routes, and a control freeway.
3 Vehicle and occupancy counts on alternate arterial routes to identify any changes in throughput for the corridor, counts at park-and-ride lots, and vehicle and occupancy counts on a ■control• freeway.
4 Monitoring bus on time performance and schedule adherence before-and-after implementation of the HOV lane(s).
5 Before-and-after bus service levels, vehicle productivity, schedule adherence, number and severity of bus accidents, vehicle operating costs, and changes in labor, fuel, and other costs.
6 Tracking of public comments received by letter, e-mail, and telephone; media coverage; and legislation relating to HOV facilities.
7 Use of simulation models to estimate impact.
8 Capital and operating cost data.

CHAPTER FIVE – HOV DATA COLLECTION

Chapter-at-a-Glance

This chapter highlights the data collection techniques associated with monitoring the performance of HOV facilities. It presents information on the different methods to collect needed data and highlights case study examples from HOV projects throughout the country. The chapter contains the following sections:

- **HOV Facility Inventory**. This section highlights methods to collect, maintain, and display information on HOV facilities in a metropolitan area or a state.
- **Vehicle Classification and Vehicle-Occupancy Counts**. This section highlights techniques to collect data on the number and type of vehicles using HOV and general-purpose lanes and the number of individuals in these vehicles. Techniques for counting buses, vanpools, carpools, priced vehicles, low-emission and energy-efficient vehicles, and marked law enforcement vehicles are presented.
- **Travel Time and Travel Speed Data**. This section presents techniques to obtain travel time and travel speed data. The use of both manual and electronic methods are discussed.
- **Bus Routes and Ridership**. This section describes additional methods for collecting data on bus routes and bus riders from public transportation agencies and transit providers.
- **Park-and-Ride and Park-and-Pool Lot Use**. This section highlights methods for conducting use counts at park-and-ride and park-and-pool lots associated with HOV projects.
- **HOV Facility User and Non-User Surveys, Focus Groups, and Stakeholder Interviews**. This section presents techniques for conducting surveys, focus groups, and interviews with HOV users and non-users, the general public, and stakeholders. Examples of surveys are provided, along with tips to consider in developing and conducting surveys, focus groups, and interviews.
- **Crash Data**. This section describes methods to obtain crash data from state and local law enforcement agencies, state departments of transportation, and transit agencies.
- **Violation Rates**. This section highlights the techniques for obtaining data on citations issued for violating HOV operating requirements. Violations may include having fewer than the required number of people in a vehicle, entering and exiting the HOV lane illegally, not paying a required fee, and

other infractions. Obtaining information from the court system on the judication of violations is also presented.

- **Information Relating to Vehicle Emissions, Air Quality, and Energy Consumption**. This section describes the data typically needed to analyze the potential impact of HOV lanes on vehicle emissions, air quality, and energy consumption.

HOV Facility Inventory

Maintaining an up-to-date inventory of HOV facilities in an area provides the base for a performance monitoring program. The inventory should contain the basic information on HOV facilities including the length, operating hours, vehicle eligibility requirements, vehicle-occupancy levels, access points, and other key elements. Some agencies maintain an HOV inventory as part of a geographic information system (GIS), while others maintain the basic information in table format. The format and level of detail in the inventory can be matched to number, type, and complexity of HOV facilities in an area. An HOV inventory provides basic information that is of interest to technical agency staff, policy makers, the media, special interest groups, and the public. The WSDOT case study provides an example of an Internet-based map of the HOV lanes in the Puget Sound Region. The Caltrans case study provides an example of an HOV lane database using a spreadsheet program.

Washington State Department of Transportation (WSDOT) Web Map

WSDOT provides an updated map of the HOV system on the agency's website: http://www.wsdot.wa.gov/hov/pugetsoundeval/default.cfm.

Caltrans – HOV Inventory

Caltrans maintains an HOV inventory report in an Excel spreadsheet.

TRAFFIC OPERATIONS PROGRAM, HQ

HIGH-OCCUPANCY VEHICLE SYSTEMS BRANCH

HOV INVENTORY REPORT

EXISTING HIGH-OCCUPANCY VEHICLE LANES

District	County	Route	Post Mile	Description	Opening Date	Length (Lane-Miles)	Occupancy Requirement	Hours of Operation		Direction
3	SAC	99 51	11.9/24.4 0.0/1.8	0.8 mi S of Elk Grove Blvd to Rte-50/99/51 Sep to B St Underpass	11/90 09/99	28.6	2+	6:00-10:00 am 3:00-7:00 pm	M - F	NB SB
DISTRICT 3 TOTAL LANE-MILES EXISTING						**28.6**				
District	**County**	**Route**	**Post Mile**	**Description**	**Opening Date**	**Length (Lane-Miles)**	**Occupancy Requirement**	**Hours of Operation**		**Direction**
4	ALA	80	Lanes 1, 2, 21, 22	San Francisco-Oakland Bay Bridge **Toll Plaza**	04/70	2.9	3+	5:00-10:00 am 3:00-7:00 pm	M - F	WB
4	ALA	80	3.8/8.0	Powell St to Contra Costa Co Line	02/98 11/98	8.4	3+	5:00-10:00 am 3:00-7:00 pm	M - F	WB EB
4	ALA	84	3.1/4.9	Dumbarton Bridge **Toll Plaza**	10/82	1.8	2+	5:00-10:00 am 3:00-6:00 pm	M - F	WB
4	ALA	92	R2.5/R4.5	San Mateo Bridge **Toll Plaza**	10/89	2.0	2+	5:00-10:00 am 3:00-6:00 pm	M - F	WB
4	ALA	880	0.0/1.2	16th St to SFOBB **Toll Plaza**	05/98	1.2	3+	5:00-10:00 am 3:00-7:00 pm	M - F	NB
4	ALA	880	2.4/22.7	Mission Blvd (Rte-262) to Marina Blvd	09/91	37.2	2+	5:00-9:00 am 3:00-7:00 pm	M - F	NB SB
4	CC	4	R16.2/20.3	Port Chicago Hwy to Bailey Rd	06/00	4.1	2+	6:00-9:00 am	M - F	WB
4	CC	80	0.0/9.9	Alameda Co Line to Rte-4	05/97	19.6	3+	5:00-10:00 am 3:00-7:00 pm	M - F	WB EB
4	CC ALA	680	R0.0/R11.4 R21.3/R21.9	Alcosta Blvd to Livorna Rd	10/94	24.5	2+	6:00-9:00 am 3:00-6:00 pm	M - F	NB SB
4	MRN	101	4.0/8.4	Richardson Bay Bridge to Greenbrae I/C	12/74	7.2	2+	6:30-8:30 am 4:30-7:00 pm	M - F	SB NB
4	MRN	101	12.8/18.9	North San Pedro Rd to Rte-37	08/86 07/87	12.2	2+	6:30-8:30 am 4:30-7:00 pm	M - F	SB NB
4	SCL	85	0.0/23.8	Rte-101 (South San Jose) to Rte-101 (Mountain View)	02/90 04/90	47.1	2+	5:00-9:00 am 3:00-7:00 pm	M - F	NB SB

Vehicle Classification and Vehicle-Occupancy Counts

Vehicle classification and vehicle-occupancy counts represent basic data elements for monitoring the performance of HOV facilities. These counts measure the number of vehicles and the number of passengers or occupants per vehicle, in both the freeway general-purpose lanes and the HOV facility. Comparing changes in these two variables before construction begins on a project, after the HOV facility is open, and on an ongoing basis provides the information needed to monitor the objectives related to increasing person movement efficiency, cost effectiveness, impacts on energy consumption and air quality, and freeway operations. In addition, vehicle and vehicle-occupancy data are critical to evaluating potential changes in occupancy requirements that may be necessary in response to increased demands or legislative action.

Vehicle and vehicle-occupancy counts should be taken on the HOV facility, the general-purpose freeway lanes, and, if possible, parallel routes and a control freeway. Consideration should also be given to conducting counts on the freeway frontage roads, if they exist in the corridor. The number of count sites, and the exact count location, should be determined based on the length of an HOV facility and the number and location of access points. Further, the count sites should be selected based on the ability to clearly and accurately see vehicles and maintain safety for personnel conducting the counts.

Training for personnel conducting the vehicle and vehicle-occupancy counts should be conducted a week before the actual data collection. Training should cover the exact procedures to be used to identify and record the vehicle classification and vehicle-occupancy counts. Personnel should be provided with the necessary safety equipment, which may include safety vests, hard hats, and steel-toed boots, and recording equipment. The safety aspects of the data collection efforts should be stressed. Personnel should be provided with on-site training, with the supervisor reviewing each step of the procedure and the individual conducting a test data collection process.

Manual Count Techniques

The manual count technique for conducting vehicle and occupancy counts relies on human observers in the field. Count locations for the HOV lanes, freeway lanes, and frontage roads should all be in the same general area, although safety and visibility concerns may influence the exact sites. At a minimum, at least one count location should be used to collect vehicle and occupancy information for both the HOV lane and the freeway mainlanes. This site should be located at the highest HOV volume point if possible. More than one location should be considered if major access/egress points influence the volumes on either the HOV lanes or the general-purpose lanes.

Examples of the location of a freeway count station and an HOV lane count station are provided in Figures 5.1 and 5.2. On freeways, vehicle classification and occupancy counts may be taken only on the middle or one of the middle lanes, with only vehicle counts and general classification (automobile or commercial) taken in the other lanes. The experience in Houston indicates that the occupancy data obtained for the middle lane, with the exception of buses and vanpools, provides a reasonable representation of occupancy characteristics for vehicles utilizing the freeway mainlanes in the peak direction of flow. This approach reduces the need to collect occupancy data for cars and commercial vehicles on the remaining freeway lanes. However, it is important to note that this methodology has been developed using historical data for the Houston freeway system. The variance of occupancy characteristics across freeway lanes in other urban areas may be different. Therefore, vehicle occupancy data should initially be gathered for each lane. If the trends across the lanes are similar, as they are in Houston, counting only one lane may be possible.

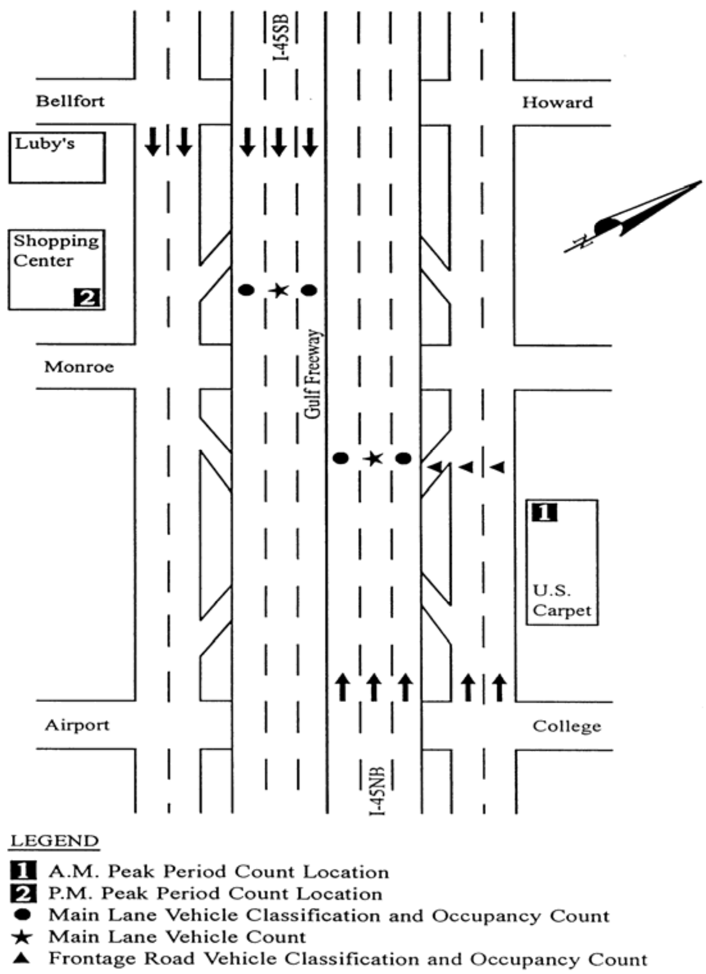


Figure 5.1. I-45 South (Gulf) Freeway Count Locations – Houston.

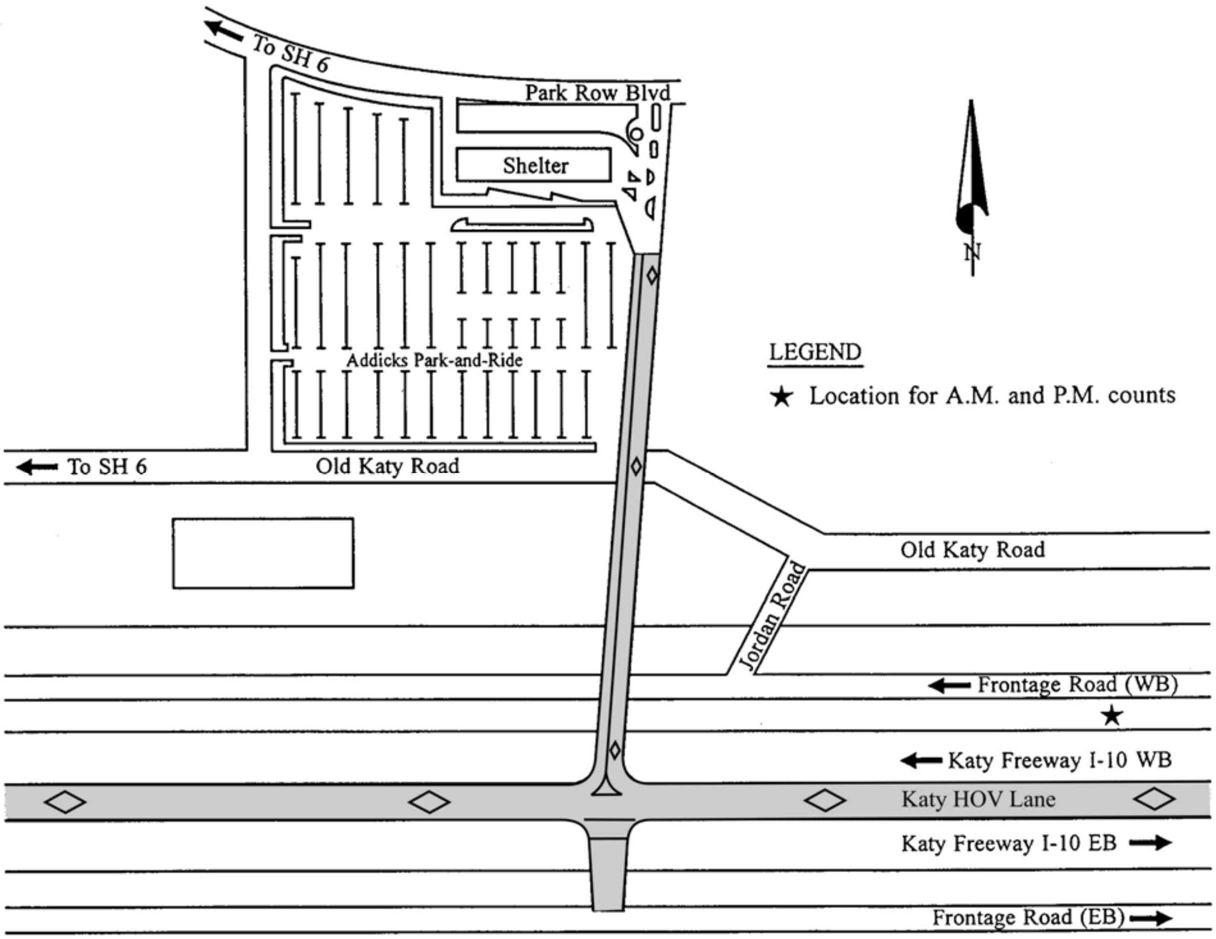


Figure 5.2. 1-10 West (Katy) HOV Lane Count Location – Houston.

The vehicle and occupancy information from the middle lane and from the other lanes are recorded on the data sheets in the Houston case studies. The occupancy rates observed in the middle lane are then applied to the vehicles in the other lanes to produce the overall person volume estimates for the entire freeway in the peak direction of flow.

In the Houston analysis, automobiles, pickup trucks, mini-vans, and motorcycles are classified as cars. Commercial vehicles include taxicabs, large emergency vehicles, delivery trucks, semi-trucks, and other large vehicles. Since buses and vanpools exhibit occupancy rates that are significantly higher in range and magnitude than those of cars or commercial vehicles, making inferences about the occupancy rates of the other lanes based on those observed in the middle lane could produce serious errors. To reduce this risk, the occupancy rates of buses and vanpools utilizing the other lanes are individually recorded on the data sheet. Figures 5.3, 5.4, and 5.5 provide examples of the forms used in Houston.

TTI VEHICLE OCCUPANCY DATA

Facility: ______________ Weather: ______________
Time: ______________ Recorder: ______________
Date: ______________ Lane: ______________

Vanpools

1-3	
4-6	
7-9	
10-12	
13+	

Buses

Empty	
1/4 Full	
1/2 Full	
3/4 Full	
Full	
Full+	

Pickups/Passenger Cars

1	
2	
3	
4+	

Commercial

1	
2	
3	
4+	

Motorcycles

Frontage Rd Volumes

Trucks 18-Wheelers

1	
2	
3	

Taxi Cabs

1	
2	
3	

Figure 5.3. Freeway Mainlane Vehicle Occupancy Data Form – Houston.

TTI BY LANE VEHICLE VOLUMES (Freeway)

Facility: ________________ Weather: ________________
Date: ________________ Recorder: ________________

Begin Time	Code Time	Lane: ________		Lane: ________		Lane: ________	
		Cars	Commercial	Cars	Commercial	Cars	Commercial
3:30	15						
3:45	16						
4:00	17						
4:15	18						
4:30	19						
4:45	20						
5:00	21						
5:15	22						
5:30	23						
5:45	24						
6:00	25						
6:15	26						
6:30	27						
6:45	28						

Figure 5.4. Freeway Mainlane Vehicle Volume Data Form – Houston.

HOV OCCUPANCY SUMMARY

Date: ____________________

Location: ____________________ Observer: ____________________

Time	Buses						Vanpools					Carpools				
	E	1/4	1/2	3/4	F	F+	1-3	4-6	7-9	10-12	13+	1	2	3	4	5+
3:30 P.M.																
3:45 P.M.																
4:00 P.M.																
4:15 P.M.																

Figure 5.5. HOV Lane Vehicle-Occupancy and Classification Data Form – Houston.

Keys to Success – Vehicle and Vehicle-Occupancy Counts

Based on experience, the following tips can help ensure conducting successful vehicle classification and vehicle-occupancy counts.

- **Data Collection Site Selection**. Careful consideration should be given to selecting the site for conducting the vehicle classification and vehicle-occupancy counts. The site should be at a maximum use point along the HOV and freeway facility. The number and location of access points should be considered in selecting the general data collection location. The specific site should provide a clear view of the HOV and the general-purpose lanes to be counted. The site should provide a safe location for the data collection vehicle and the data collection personnel. The site should also not impact the safety of motorists.
- **Training for Data Collection Personnel**. Training should be provided for data collection personnel a week before the actual counts. Training should include a classroom session focusing the proper data collection procedures, safety equipment, and safety procedures. On-site training should also be provided, allowing personnel to complete a test data collection effort.
- **Conducting Vehicle and Vehicle-Occupancy Data Collection**. On the actual days of data collection, field personnel should arrive at their count location at least 15 minutes before the scheduled start time. Field personnel should have all the equipment needed – counting board or hand held computer, forms and pencils, watch or count-down timer, safety equipment, and water. Field personnel should record any special occurrence during their shift that may influence traffic patterns and the validity of the data collection. Examples of occurrences to note include significant rain or snow storms or other hazardous weather, crashes, and other incidents.

In the Houston evaluation, the observed general bus passenger levels are translated into occupancy rates based on the utilization levels identified in Table 5.1. A person-carrying capacity of 50 persons is used for all regular buses, including standard buses, school buses, and charter buses. The capacity of articulated buses is estimated to be 70 persons. Since it is often difficult to observe passenger levels through the tinted bus windows, the accuracy of this procedure is checked periodically by physically counting the number of individuals boarding buses at selected locations. These methods and obtaining ridership data from transit agencies and operators are discussed later in this section. These detailed counts are compared to the survey results, and adjustments to the estimating process are made as needed.

Table 5.1. Bus Person Volume Estimates for Different Passenger Utilization Levels.

Type of Bus	General Status of Bus Occupancy[1]	Estimated Number of Persons Aboard Bus[2]
Standard Size3	Empty	1
	1/4 Full	10
	1/2 Full	20
	3/4 Full	30
	Full	40
	Full +[4]	50
Articulated5	Empty	1
	1/4 Full	15
	1/2 Full	30
	3/4 Full	45
	Full	60
	Full +[4]	70

1 Estimated portion of bus that is occupied by passengers.
2 Corresponding estimate of the number of passengers based on a seating capacity of 40 persons for standard size buses and 60 persons for articulated buses.
3 Includes Metro buses, school buses, and charter buses.
4 Refers to the ultimate capacity of the bus; all seats full and passengers standing in the aisle.
5 Refers to Metro buses that are longer than standard size buses and that have a permanent hinge near the center which allows maneuverability.

Field personnel view and record each vehicle and the number of occupants in the vehicle for a specific lane for a specific time period, typically 15-minute increments. Personnel record the information on pre-printed data forms. Handheld computers or data recorders may also be used.

In Houston, vehicle and occupancy counts are also collected at eight locations on alternate parallel routes. These counts are conducted to assist in identifying the potential impacts of the HOV lanes on parallel alternate routes. The same data collection forms utilized for the middle freeway lane are used on these facilities. The same general procedure used for the freeway counts are used on the alternate parallel routes.

Electronic Count Techniques

Other techniques can be used to obtain vehicle and occupancy data. For example, road tubes and loop detectors may be used to collect vehicle count data. In the some areas, inductance loop detectors are used to monitor the entire freeway system, including the HOV lanes. In the Washington, D.C. area, ongoing data collection activities include the Metro Core Cordon Counts and Beltway Cordon Counts, and screen line volume, mode, and occupancy counts. Data from these efforts are used to evaluate the Shirley Highway and the I-66 HOV lanes. Closed Circuit Television Cameras (CCTV) represent another possible approach. This technique is currently being used in the Minneapolis-St. Paul area. CCTV loop detectors are utilized on parts of the freeway system, including the HOV lanes on I-394.

Although these technologies are being used successfully to obtain vehicle count and classification data, less positive results have been realized in attempts to obtain vehicle occupancy data through the use of CCTV or other video technologies. Both Orange County and Houston have experimented with the use of video technology to monitor vehicle occupancy rates. The results obtained through these efforts generally were not as accurate as those obtained through manual methods. The primary reason for the lower degree of accuracy stems from the static limitations of the video technology and the reproductive limitations of the film or television. Thus, the use of these technologies for vehicle counts are often supplemented with manual vehicle occupancy counts.

Special Vehicle Counts

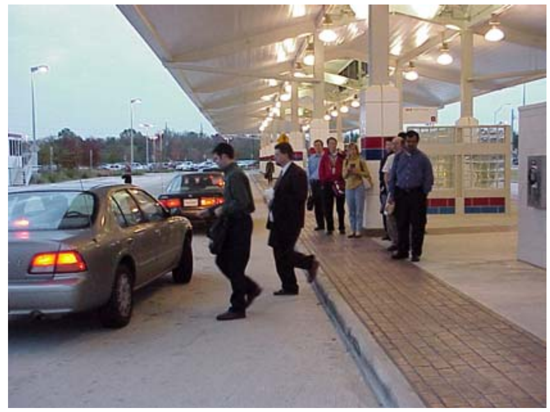
If special vehicles are allowed to use an HOV lane, the monitoring program should record their use. Examples of special vehicles might include priced vehicles, low-emission and energy-efficient vehicles and marked law enforcement and emergency vehicles. These vehicles will need to be recorded by visual observation, with the exception of priced vehicles, which may be monitored through electronic toll collection methods. The WASHCOG case study highlights counting vehicles with special fuel license plates using the HOV lanes in northern Virginia. The Houston case study highlights counting casual carpoolers, or slugs, as they are referred to.

WASHCOG Counts of Clean Special Fuel Vehicles

Virginia allows low-emission and energy-efficient vehicles with clean special fuel license plates to use the HOV lanes in the state without meeting vehicle occupancy requirements. In the fall of 2003, WASHCOG started recording the number of vehicles with clean special fuel license plates using the HOV lanes as part of their ongoing HOV performance monitoring program. Individuals stationed at the count locations record the number of vehicles with clean special fuel license plates as other personnel are counting vehicles and occupants.

Counting Casual Carpoolers in Houston

Casual carpooling is the term used to describe the practice of drivers or two-person carpoolers sharing a ride with one or more individuals to meet the vehicle-occupancy requirements on an HOV facility. The drivers are referred to as body snatchers and the people waiting for rides are called slugs. Casual carpooling is known to occur on the I-395 (Shirley Highway) HOV lanes in northern Virginia/Washington, D.C., the HOV lanes approaching the Bay Bridge in the San Francisco/Oakland area, and on the I-10 West (Katy) and US 290 (Northwest) HOV lanes in Houston. TTI personnel conducted counts of casual carpoolers at two park-and-ride lots on the I-10 West HOV lane and one park-and-ride lot on the US 290 HOV lane in 2003 as part of the QuickRide Demonstration project. The three locations were selected based on information from METRO and other agency personnel about where casual carpooling was occurring. To conduct the counts, field personnel positioned themselves near the platform where the casual carpoolers line up for the rides. Counts of the number of people accepting rides were recorded on forms in 15-minute intervals.



Travel Time and Travel Speed Data

Travel time and travel speed data represent the second most common type of information needed to evaluate HOV facilities. Travel time data measure the time it takes a vehicle to travel a certain distance. The travel time data are used to help determine travel time savings and trip time reliability, the benefit-cost ratio, energy consumption and air quality impacts, and freeway operational impacts.

Travel time data for the freeway and HOV facility may be obtained using a number of methods. The techniques for collecting travel time data have evolved over the past few years. The availability of computers and advanced technologies has enhanced data collection efforts. The widespread use of ITS technologies, including Advanced Transportation Management Systems (ATMS) and Transportation Management Centers (TMCs) have further allowed for automatically collecting and processing speed and travel time data. More detailed information on these techniques is available in the FHWA document, *Travel Time Data Collection Handbook*, noted in the references.

Test Vehicle Techniques

The simplest data collection technique is the use of the “floating car” method. This refers to the use of a test vehicle making a series of trips along the HOV lane and the general-purpose lanes to obtain travel times. The technique is based on the concept that the test vehicle should travel at the average speed of other traffic without exceeding the speed limit.

Travel time runs are typically conducted during the morning and evening peak-periods in the peak direction of travel, with the test vehicles dispatched at 30-minute intervals. There are two people per vehicle needed to conduct the travel time runs: one to drive and one to monitor the stopwatch and record the results or operate the computer and the electronic distance-measuring instrument (DMI). Ideally, travel time runs should be conducted at the same time on both the HOV facility and freeway lanes. To accomplish this, it is usually necessary to have between two-to-four vehicles making the travel time runs. The exact number of vehicles and corresponding personnel depends on the length of the HOV facility and travel speeds.

Figures 5.6, 5.7, and 5.8 provides an example of the floating car technique and the forms used to collect data. The specific procedure consists of the driver beginning at a designated starting point with the passenger setting a stopwatch at zero. The driver begins traversing the freeway using the floating car technique, while the observer notes the elapsed time at predetermined mile points on the form shown in the Houston case study. If at any time, the traffic flow conditions on the freeway cause the driver to travel at a speed below 35 mph, which is considered to be the upper range of travel speed indicating traffic congestion on freeways, the passenger records the mile point, time at which the vehicle speed was reduced to less than 35 mph, and the apparent cause of the slow down on the data sheet. After the test vehicle regains a speed of 35 mph, the mile point and time are again noted. Thus, the length and nature of the traffic congestion problem is recorded.

The same general approach is used for conducting the HOV lane travel time runs, with slight modifications. The floating car begins at the same designated starting point used in the freeway runs. This point is prior to the entrance to the HOV facility. The passenger starts the stopwatch at this point as the vehicle starts along the freeway. The vehicle progresses along the freeway, enters the HOV lane, progresses the length of the HOV lane, and reenters the freeway traffic lanes. Throughout the trip, the passenger records the time at various checkpoints on the data form. The drivers are instructed to maintain the travel speed of other vehicles in the lane, but not to exceed the speed limit. As with freeway travel time runs, the passenger records both the duration and reasons for travel speeds falling below 35 mph.

In addition to recording decreases in travel speed below 35 mph, construction zones, weather, lighting and pavement conditions, and incidents should also be noted, regardless of whether or not they cause a significant reduction in travel speed. It is important that when the test vehicle is used, the entrance and exit points of the HOV lane should be designated as checkpoints for recording the elapsed time. This will ensure that the travel time checkpoints will be the same for both the freeway and the HOV lanes, allowing comparability between results.

The floating car technique can be enhanced with the use of an electronic DMI connected to a laptop computer. This approach involves attaching the sensor of the electronic DMI to the transmission of the test vehicle. The DMI, which operates like an odometer, receives consecutive pulses from the transmission while the vehicle is moving. The frequency of the pulses are directly related to the distance traveled. The electronic DMI translates the number of pulses to an equivalent distance. When calibrated appropriately, the DMI can provide speeds up to every 0.5 seconds. The data can be automatically downloaded to a portable computer. This technique is being used in Houston and Dallas with HOV evaluation programs and in other areas.

Advantages of the electronic DMI procedures include enhanced safety and accuracy, reduction in personnel needs, and faster data reduction capabilities. Potential disadvantages include equipment costs, ongoing maintenance needs, and added staff expertise.

Global positioning system (GPS) receivers are becoming more a popular alternative to DMI equipment in collecting travel time and speed data. GPS receivers offer the advantage of being very portable between data collection vehicles, as well as powerful data analysis and visualization tools within a geographic information system (GIS). There are several commercially available GPS/GIS systems that can be used to automate data collection procedures.

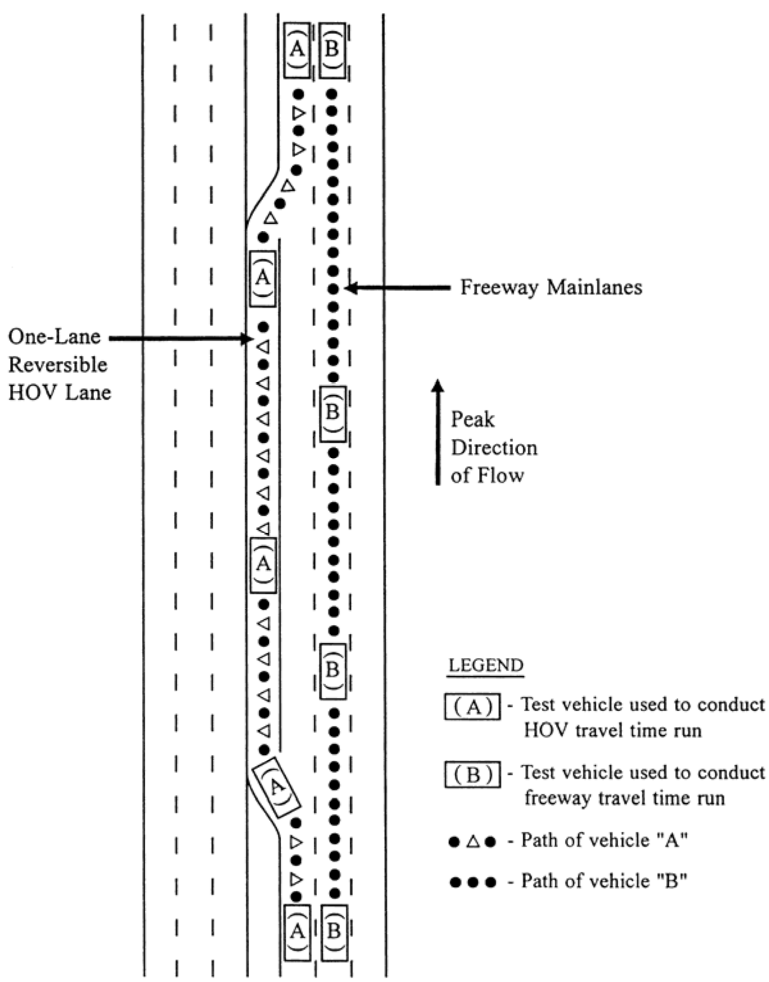


Figure 5.6. Example of Test Vehicles Conducting Travel Time Runs – Houston.

Highway: Northwest (US 290) Run Date: 6/14/90 Time Run Start: 7:30 a.m.

Direction: SB Mile Run Start: 946.9

Section Limits	Mile Point	Clock Time	Remarks				Queue		Construction	
			Weath	Light	Pave	Incid	Mile	Time	Type	Mile
Telge	-----	-----								
Huffmeister	1.60	1.40								
* FM 1960	0.95	2.38								
Eldridge	1.25	3.57								
Jones Rd.	1.42	5.24								
FM 529	1.20	6.26								
Senate	0.42	6.57								
W. Little York	1.00	8.07								
Gessner	0.45	10.06								
Fairbanks	1.15	12.45								
W. Tidwell	1.05	14.26								
Hollister	0.30	14.47								
Pinemont	1.00	16.05								
Bingle	0.30	17.26								
Antoine	1.35	20.33								
W. 34th	0.45	21.21								
Mangum	0.85	25.06								
** I-610 Overpass	0.75	28.17								
SPRR @ I-10	2.20	32.03								
Washington	0.92	32.95								
Shepherd	1.20	34.23								
Taylor	1.70	36.20								
Hogan St.	1.00	37.35								

Adjacent freeway travel time = 25 minutes and 39 seconds (25.65 minutes) [bracketed against the rows from Eldridge to I-610 Overpass]

* Entrance point to HOV lane during morning operations
** Exit point of HOV lane during morning operations

Figure 5.7. Freeway Travel Time Data Form Used – Houston.

Highway: Northwest (US 290)   Run Date: 6/14/90   Time Run Start: 7:30 a.m.

Direction: SB   Mile Run Start: 85.7

Section Limits	Mile Point	Clock Time	Remarks				Queue		Construction	
			Weath	Light	Pave	Incid	Mile	Time	Type	Mile
Telge	-----	-----								
Huffmeister	1.60	1.37								
* FM 1960	0.95	2.29								
Eldridge	1.25	3.41								
Jones Rd.	1.42	4.11								
FM 529	1.20	5.06								
Senate	0.42	6.20								
W. Little York	1.00	6.47								
Gessner	0.45	7.53								
Fairbanks	1.15	8.23								
W. Tidwell	1.05	9.32								
Hollister	0.30	10.37								
Pinemont	1.00	10.59								
Bingle	0.30	11.55								
Antoine	1.35	13.41								
W. 34th	0.45	14.08								
Mangum	0.85	15.02								
** I-610 Overpass	0.75	15.56								
SPRR @ I-10	2.20	18.21								
Washington	0.92	20.20								
Shepherd	1.20	22.36								
Taylor	1.70	24.12								
Hogan St.	1.00	25.24								

(Bracketed Eldridge through I-610 Overpass:) Transitway travel time = 13 minutes and 27 seconds (13.45 minutes)

* Entrance point to HOV lane during morning operations
** Exit point of HOV lane during morning operations

Figure 5.8. HOV Lane Travel Time Data Form Used – Houston.

License Plate Matching

Another technique for collecting travel time information involves recording license plate and time information at specific points along the freeway and HOV facility. This information can be recorded manually or recorded into laptop computers. Figure 5.9 provides an example of the use of this method. Individuals stationed at locations "A" and "B" record the license plate data and time for passing vehicles. If laptop computers are used, the time of the entry is recorded automatically. If the manual method is employed, both the time and the license plate information must be recorded. Depending on the method used, a series of computer programs are used to match the license plates and compute the travel times for vehicles between the two points.

Advantages of the license plate matching technique include ease of use, relatively low cost, and simple equipment needs. Disadvantages of this technique include the difficulty of collecting large amounts of data and the significant staff time needed to transcribe the license plate numbers for matching.

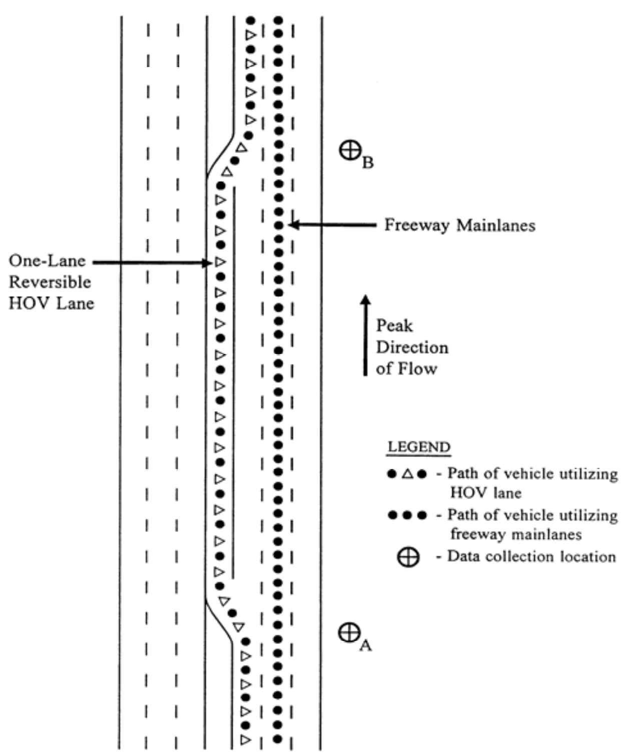


Figure 5.9. Data Collection Locations for License Plate Matching Techniques.

Advanced Transportation Management Systems and Transportation Management Centers

Most major metropolitan areas have ATMS and TMCs that monitor freeways and freeway HOV facilities. These systems may include CCTV, inductance loops, information dissemination techniques, and traffic control devices. The data obtained from these systems can be used to provide travel time, travel speed, and trip time reliability information on the HOV lanes and the general-purpose lanes. The FLOW system in the Puget Sound region, TranStar in Houston, and NaviGAtor in Atlanta are being or could be used to obtain data needed for HOV performance monitoring programs.

Houston Automatic Vehicle Identification Case Study

The use of Automated Vehicle Identification (AVI) technologies represents still another technique for collecting travel time data. This methodology is being used on the Houston HOV lanes. This procedure uses the data collected from the AVI system on the Houston freeways and HOV lanes to obtain travel times and other information on vehicles traveling on both facilities. The AVI traffic monitoring system was initiated in Houston in the early 1990s, and currently covers most of the freeway system in the area. It is part of TranStar, the TMC for the area.

The AVI traffic monitoring system is comprised of four major elements. First, AVI reader antennas are located along the freeways and the HOV lanes at approximately 1.6 to 8 kilometers (1-to-5 miles). The second component is AVI tags placed on the front windshield of vehicles traveling on the freeway system. In Houston, toll tags were given to commuters as part of the initial demonstration. In addition, vehicles with tags from the toll roads in Houston are picked up by the readers. Third, roadside reader cabinets relay the transponder identification numbers to TranStar, the transportation management center in Houston. Fourth, a software system has been developed to analyze the data and display it on a real-time traffic map. The data collected through the system is being used to examine travel time information for the HOV lanes and the general-purpose freeway lanes. A wealth of historical data is available from this system.

FLOW Traffic Management System – Puget Sound Region

The HOV facilities in the Seattle area are part of the WSDOT FLOW system covering the Puget Sound Region. The FLOW system represents a coordinated network of traffic monitoring, measuring, information dissemination, and control devices. Traffic monitoring elements include CCTV; traffic measuring devices including inductance loops; information dissemination devices including variable message signs (VMS), highway advisory radio (HAR), the WSDOT website; and traffic control devices, such as the HOV lanes and freeway entrance ramp meters. Raw traffic data from the FLOW system is retrieved and reformatted through a series of steps to compile an average daily site profile, and average daily corridor profile, and an average speed and travel time profile. An example report is available at http://depts.washington.edu/trac/bulkdisk/pdf/623.1.pdf or http://depts.washington.edu/trac/bulkdisk/pdf/584.2.pdf.

Archived data from traffic operations systems may also be used for HOV and freeway performance monitoring. This data source typically includes traffic volumes, spot speeds, and estimated or measured travel times. Archived operations data also can include causal information about freeway performance, such as traffic incidents and special events, work zones, or weather. When integrated, these archived data sources can provide significantly better performance information than the transportation profession has ever had. Archived data sources are not perfect, and several issues, such as accuracy, consistency, completeness, and coverage, must be addressed before archived data is a reliable source of performance information. Additional information on using archived data for performance monitoring can be found at http://mobility.tamu.edu/mmp.

Bus Routes and Ridership

Buses are an important element of many HOV projects. Monitoring the number of bus routes operating on an HOV lane, the number of buses providing service on the routes, and the number of bus passengers are important components of an HOV performance monitoring program. Each of these elements should be documented before an HOV facility opens and monitored on an ongoing basis.

Information on the routes using an HOV lane can be obtained from the local transit agency or bus operator. As with the HOV inventory, it is recommended that an inventory of the bus routes using an HOV lane be established and maintained. Included in this inventory should be the route, the level of service or headways on the route, and the number and type of buses used to operate service. This inventory provides the ability to track increases or decreases in transit levels on an HOV lane.

As noted previously, the number of passengers on HOV lane buses may be estimated as part of a visual vehicle occupancy count process. The visual observation method has limitations, however. First, it provides only an estimate of the number of passengers on a bus. It is difficult to track specific changes in ridership based only on these estimates. Second, the use of tinted bus windows and "wrapped buses" for marketing and promotional activities greatly reduces the ability to clearly see inside a vehicle to count passengers. To address these limitations, consideration should be given to obtaining ridership information directly from a transit agency or operator or through additional counts of passengers as buses leave a transit center or park-and-ride lot.

Many transit agencies monitor passengers on a daily or regular basis, either through on-board electronic passenger counters or through counts by the vehicle operator. These counts can be obtained and used in an HOV performance monitoring program. In addition, field personnel can count the number of passengers on a bus at a transit station or major stop before the HOV lane segment of the trip.

Most transit systems have on-vehicle systems that gather boarding counts. Electronic registering fare boxes are very common in the industry. These fare boxes record cash transactions and electronic fare media, including swipe passes and smart cards. Boardings that do not involve cash or electronic media, such as transfers, require the bus operator to touch a number on a keypad attached to the fare box. These boardings are then included in the total count. Some transit agencies use an Automatic Passenger Counting (APC) system. APCs are installed in bus doorways and usually use a series of light beams to track both boardings and alightings.

HOV Lane Bus Use and Ridership

Establishing and maintaining an inventory of bus routes using an HOV lane, and the ridership levels on those routes is an important element of an HOV performance monitoring program. The following elements should be considered for inclusion in the bus route inventory and the ongoing monitoring of bus services using the HOV lanes and ridership levels.

List of routes using an HOV lane and map of routes.

Number and type of bus operating on the routes. It is suggested that bus assignments be documented by time period – morning peak period, mid-day, afternoon peak period, and evening. The scheduled headways for buses should be monitored to document increases or decreases in service. The type of buses used, such as standard transit buses, over-the-road coaches, and articulated buses should also be recorded.

The number of passengers by bus and by route for the different time periods should be collected at regular intervals as part of the ongoing performance monitoring program.

The data collected through either system may be transmitted periodically to a central computing source, or, more typically, is downloaded from the bus at the operating base. The data can be tabulated in various ways – by bus, by route, and by hour of the day. The APC data has the further advantage of recording alightings, so it can be used to review load factors along a route.

Manual counting of passengers is still used by some transit agencies. Manual counts may be conducted by a bus operator and recorded on trips reports that are later gathered and tabulated. Field personnel may count passengers at fixed locations such as park-and-ride lots or by riding a bus and noting the number of riders boarding and alightings by stop. Manually counting is becoming increasingly rare with the continuous advances in automated technology, however.

To obtain HOV lane bus ridership information, a transit agency or operator must complete the following steps, assuming the use of automated data collection.

- Identify the specific bus trips that use an HOV lane.
- Identify the buses used to operate those trips.
- Obtain automated ridership counts from those buses.
- Identify which portion of the passenger count data relates to the HOV lane trips. The data is usually by time-of-day or by individual trip.
- Identify the number of passengers on-board the vehicle while it operated on the HOV lane. Many bus routes that use HOV lanes start at park-and-ride lots or have a limited number of steps where passengers board prior to entering the HOV lane. In these cases, the HOV lane passenger count is the sum of all boardings. In some cases, however, a bus route using an HOV lane may serve a neighborhood area and have boardings and alightings prior to entering an HOV lane. If a bus is equipped within an APC system, the number of passengers on the HOV lane segment can be easily determined. If a bus uses a registering fare box, only boardings are recorded. Determining ridership on the HOV segment is based on an estimate of alightings prior to entering the HOV lanes as determined from periodic manual counts.

Regardless of the passenger counting method used by the transit agency or operator, the information needed for an HOV performance monitoring program is the number of riders on-board a bus as it travels in the HOV lane. As discussed in the next chapter, establishing the passenger counting procedures to be used by the transit agency or operator should occur during the development of the data collection program.

Park-and-Ride and Park-and-Pool Lot Use

Information on the use of park-and-ride and park-and-pool facilities is typically obtained through periodic manual counts. Usually, the number of vehicles parked at each facility is recorded during the middle of the day (between 9:00 a.m. and 3:00 p.m.) on weekdays.

Depending on the size of the lot, data collection personnel may walk or drive the lot. If the lot is well used, it may be easier for field personnel to count the number of vacant spaces in a row and subtract from the total spaces in the row. Figure 5.10 provides an example of the data collection form used at park-and-ride lots along the HOV lanes.

Month:________________
Project:________________

Freeway Corridor	Name of Lot	Number of Parked Vehicles	Date
Katy (I-10W)	1. Kingland		
	2. Fry		
	3. Addicks		
	4. West Belt		
	5. Mason		
	6. Barker-Cypress		
North (I-45N)	1. N. Shepherd		
	2. Kuykendahl		
	3. Spring		
	4. Seton Lake		
	5. Woodlands		
Gulf (I-45S)	1. Edgebrook		
	2. Bay Area		
Southwest (US 59S)	1. Sharpstown		
	2. West Loop		
	3. Westwood		
	4. Alief-Boone		
	5. Missouri City		
Eastex (US 59N)	1. Kingwood		
	2. Eastex		
Northwest (US 290N)	1. NW Station		
	2. W. Little York		
	3. Pinemont		
I-10E	1. Maxey		

Figure 5.10. Houston Park-and-Ride Lot Data Collection Form.

The license plates of parked vehicles may also be recorded as part of a mail-out/mail-back survey or to identify the travel shed from a specific facility. Field personnel record the license plate number for each parked vehicle, leaving a blank if a parking space is unoccupied. Most areas record only in-state plates, as information on out-of-state plates is not available from the state department of motor vehicles. In addition to the license plate number, field personnel should note any specialized plate in the "type" column.

HOV Facility User and Non-User Surveys, Focus Groups, and Interviews

Surveys, focus groups, interviews, and other market research techniques are frequently used as part of a HOV performance monitoring program to help identify changes in mode choice and the reasons for these changes, the perceptions of users and non-users toward utilization of an HOV facility, and to obtain socio-economic, demographic, and general travel information on commuters in the corridor. A better understanding of these elements is important in evaluating many HOV project objectives, especially those relating to mode shift and public support.

The survey technique used as part of an HOV performance monitoring program should be matched to the type of information needed from users and non-users, the intended use of the information obtained, and the level of statistical validity desired. There are two basic types of survey research techniques that may be used in HOV performance monitoring programs – qualitative and quantitative. The difference between the two approaches relates to the level of statistical validity of the information generated by specific techniques and the ability to draw inferences to the population as a whole. In general, qualitative techniques involve small numbers of people who typically are not selected randomly. Quantitative methods include samples of individuals that are randomly selected or are drawn from representative samples.

Focus groups and general interviews are examples of qualitative techniques. These approaches may be used to obtain in-depth information on a topic from a specific group, to identify issues for subsequent quantitative surveys, and to examine emotional and other issues that influence travel decision making. For example, focus groups may be conducted with carpoolers to obtain their reactions to pricing strategies or interviews may be conducted with key stakeholders to identify perceptions related to HOV facilities or pricing options.

Examples of quantitative techniques that may be used in HOV performance monitoring programs include on-board transit surveys, telephone surveys, mail surveys, intercept surveys, and on-line surveys. These methods can be used to help identify behavior and to measure awareness and attitudes with a known degree of accuracy and confidence.

As described in this section, the key in HOV performance monitoring programs is to match the appropriate methodology to the issues being examined, the information desired, the scope of the project, and available resources. In some cases, more than one technique may be used as part of an HOV performance monitoring program. For example, focus groups may be used initially for exploratory research or after a survey to confirm research. Results from focus groups are often used to help design survey questions or to better understand the meaning of the results from surveys with statistically reliable samples. Mail surveys are typically sent to carpoolers, vanpoolers, and motorists in the general-purpose lanes. Surveys distributed to passengers as they board a bus and collected as they exit the vehicle are typically used to obtain information from riders. Telephone surveys and on-line surveys may be used to obtain information from the general public in an area. Finally, interviews may be conducted with policy makers and other key stakeholders.

State departments of transportation, transit agencies, and other public agencies may use professional firms, local universities, transportation institutes, and other groups specializing in conducting surveys and focus groups to assist with specific projects. The need for these services will depend on the internal staff expertise and resources available at a transportation agency, the nature of the survey and available funding. There are advantages and disadvantages with using these groups. If an outside firm is used, the public agency should still have staff knowledgeable in these areas to direct the activities.

Market research firms, universities, and transportation institutes specialize in identifying the appropriate survey techniques for use in analyzing specific issues or topics and conducting the actual study. These groups may offer services related to designing, recruiting participants and conducting focus groups; developing survey instruments, drawing random samples, and conducting telephone or self-administered questionnaires; conducting executive interviews; and analyzing the results of all these techniques. Utilizing an outside group can help ensure that the most appropriate survey techniques are used, that the process and results are reliable and valid, and that adequate rigor is applied to the analysis process. Further, multiple groups may be involved depending on the nature and the scope of a project. For example, a market research firm or university group may develop the approach, focus group script, and survey instrument. Professional focus group facilitators and call centers may be used to conduct the specific tasks.

Conducting on-board transit passenger surveys and mail-out surveys of carpoolers and vanpoolers using the HOV lane, and motorists in the general-purpose freeway lanes are described in this section. The use of intercept surveys targeted at specific user groups is presented. Information is also provided on telephone surveys, focus groups, stakeholder interviews, and on-line surveys.

On-Board Passenger Surveys

Surveys of bus riders are frequently conducted as part of HOV performance monitoring programs. These surveys are an important method to obtain information on HOV lanes attracting travelers to change from driving alone to riding the bus and other related factors. Key elements in developing and administering on-board surveys include questionnaire design, sample selection, surveyor recruitment and training, and survey administration.

On-board questionnaires should focus on the key information needed from riders. Typical questions address trip purpose, trip origin and destination, previous mode of travel, reason for using the bus, the importance of the HOV lane in mode selection, access mode, automobile availability, perceived travel time savings from the HOV facility, perception of HOV lane utilization, and socio-economic characteristics. Figure 5.11 highlights one example of an on-board bus passenger questionnaire.

This survey is being undertaken by the Texas Transportation Institute, the Texas Department of Transportation, and METRO in order to obtain information about your use of the North HOV Lane. Please take a few minutes to answer the questions below and return this form to the survey taker before leaving the bus.

1. What is the purpose of your bus trip this morning? ___ Work ___ School ___ Other

2. What is the Zip Code of the area where this trip began? (For example, if this trip began from your home this morning, you would list your home Zip Code.)

3. What is your final destination on this trip? ___ Downtown ___Galleria/City Post Oak/Uptown
___ Texas Medical Center ___ Greenway Plaza ___ Other (specify Zip Code ______)

4. Have you ever carpooled or vanpooled on the HOV lane? ___ Yes, carpooled ___ Yes, vanpooled
___ No

5. How important was the opening of the North HOV lane in your decision to ride the bus?
___ Very Important ___ Somewhat Important ___ Not Important

6. If the North HOV lane had not opened, would you be riding a bus now?
___ Yes ___ No ___ Not sure

7. How many minutes, if any, do you believe this bus presently saves by using the North HOV lane instead of the regular traffic lanes? _____ Minutes in the Morning _____ Minutes in the Evening

8. How long have you been a regular bus rider on the North HOV lane?

9. Does your employer pay for any part of your bus pass? ___ Yes, all ___ Yes, part ___ No

10. Was a car (or other vehicle) available for this trip? (Check one) ___
___ No, bus was only practical means ___ Yes, but with considerable inconvenience to others
___ Yes, but I prefer to take the bus

11. Before you began riding a bus on the North HOV lane how did you normally make this trip? (Check one)
__ Drove alone
__ Carpooled
__ Vanpooled
___ Rode a park-and-ride bus on the regular freeway lanes
___ Rode a regular route or express bus
___ Did not make this trip prior to using the North Transitway
Other (specify ______________________________)

12. Do you feel that the North HOV lane is, at present, being sufficiently utilized to justify the project?
___ Yes ___ No ___ Not sure

13. What is you're... Age? _____ Sex? _____ Occupation? ____

14. What is the last level of school you have completed? _____

Comments: _____

THANK YOU FOR YOUR COOPERATION

Figure 5.11. HOV Lane Transit User Survey – I-45 North, Houston.

Since individuals will be completing the survey on the bus, using a simple, easy to complete questionnaire is essential. A one-page format is typically used with on-board questionnaires. Card stock or heavy-weight paper may be used for the survey and consideration should be given to the font size and color. Surveys should be prepared in English and Spanish. Survey may need to be prepared in other languages used by a significant number of riders. Consideration should also be given to surveying riders with special needs.

Another option is to use a mail back survey. Mail back surveys typically increase the valid sample size in the range of six percent to nine percent. The survey form can be designed to fold into a return pre-paid mailer or a pre-paid return-addressed envelope may be provided.

Selecting the sample of the bus routes and bus trips to be surveyed is the second major step in conducting an on-board survey. The sample selection process is important to ensure that all types of services and ridership groups are included, so that the results are not biased toward any one ridership group. The intent is to obtain a representative cross-section of routes, riders, and time-of-day depending on the span of service provided in the HOV lane.

The first decision in selecting the sample relates to the direction of travel. Typically, on-board surveys are conducted in the morning focusing on inbound trips. It is assumed that riders on the reverse trip – outbound in the evening – are the same or have the same characteristics as those riding the bus in the morning. The one exception to this approach is if there are reverse commute routes – routes that operate from the central city areas to the suburbs in the morning and back in the afternoon – operated on the HOV lanes. If reverse commute service is provided on an HOV facility, these routes should be included in the survey. Also, if mid-day services are provided on the HOV lane, it may be appropriate to include some of these trips in the sample.

More detailed descriptions of selecting statistically valid samples can be found in the sources listed in the references at the end of the Handbook. In general, the sample size is a function of the sample error acceptable at a specified level of confidence. To select a sample for on-board surveys, start with the total ridership on the HOV lane in the targeted direction of travel.

The sample size for a 95 percent confidence interval with a +/- 5 percent margin of error for a finite population is to target 400 valid complete surveys. More than 400 surveys will need to be handed out to ensure that 400 questionnaires are completed and returned. The number of surveys distributed will depend on the anticipated response rate. In general, on-board surveys of commuters on park-and-ride and express bus routes using HOV lanes have high response rates, often in the range of 60 percent to 90 percent. Assuming a 50 percent response rate, 800 surveys would need to be distributed. As noted previously, given the purpose and use of on-board surveys, the best rule of thumb is to obtain an adequate cross-section of routes, ridership, and time-of-day for bus services using the facility.

After the questionnaire has been designed and the sample selected, the next step in conducting an on-board survey is to recruit and train the individuals who will actually be conducting the survey. A number of approaches may be considered for recruiting surveyors, including using available transit agency personnel, hiring university students or other individuals, and using employees or contract workers from a survey research firm or university employed to conduct the survey. Regardless of the method used, the individuals selected to conduct the surveys should be polite, friendly, reliable, and willing to interact with riders.

Training for surveyors should occur a day or two days before the actual survey. Consideration should be given to conducting training, providing the surveyor with a test assignment the following day, and conducting the actual survey the third day. Training should start with an overview of the purpose of the survey and how the results will be used. Since passengers may ask surveyors these questions, it is important that they be able to respond with general information. The specific procedures and logistics for the survey should be explained. Elements to cover include starting and stopping times, assignment location, process for handing out and collecting surveys, dress, and materials needed during the survey. Techniques for surveying passengers with special needs and those who decline surveys should be addressed. Surveyors should be given the opportunity to develop and test their skills through role playing. Survey assignment bags are frequently used to provide surveyors with everything they will need during their shift. It is also suggested that the terminology associated with bus operations and the survey process be reviewed. Individual assignment sheets should be distributed and reviewed with each surveyor.

A number of actions are involved in the final step of conducting the survey. It is important to communicate the dates, times, and location of the survey to all transit personnel. These personnel include bus operators, bus dispatchers, on-site supervisors, and other individuals. Surveyors should arrive at their designated location early and have all needed materials. The use of survey assignment bags can help ensure that personnel arrive with all the items necessary for the survey. Surveyors should be polite and friendly in asking riders to complete a questionnaire. If a passenger refuses a questionnaire, the surveyor should thank them and move on to the next passenger.

If a bus starts from a transit station or park-and-ride lot the surveyor hands the surveys and pencils to passengers as they board and then boards the bus themselves. If the bus makes stops to pick up passengers prior to entering the HOV lane, the surveyor should board the bus prior to the first stop and distribute surveys and pencils to riders as they board the bus at each stop. Surveyors ride the bus to collect the questionnaires. If a bus travels directly from a transit center or park-and-ride lot to a major destination, personnel at the destination may collect the surveys from the buses. However, this approach may reduce the response rate. Finally, surveyors should be provided with customer service cards they can give to passengers with questions or comments.

Planning Successful On-Board Bus Ridership Surveys

Based on experience, the following tips can help ensure planning a successful on-board bus ridership survey.

- **Questionnaire Design**. The on-board survey should be short and easy to complete. It should focus on the key information needs. Questions typically address trip purpose, trip origin and destination, previous mode of travel, reasons for bus use, travel time savings, importance of HOV lane in bus use, mode of access, automobile availability, and socio-economic characteristics. In addition to surveys in English and Spanish, questionnaires in other languages may be needed.
- **Questionnaire Format and Printing**. The format of the survey should be simple and easy to read. Consideration should be given to using card stock or heavy weight paper. The font size and paper color may also enhance the ability to read and complete the survey. A one-page format is typically used.
- **Sample Selection**. The survey sample should be selected to obtain a cross-section of routes and riders using the HOV lane, as well as the time-of-day. Typically, commuter surveys will be conducted in one direction of travel. Usually the morning inbound direction of travel is used, with the assumption that riders in the evening outbound trip are the same or reflect the same characteristics. If reverse commute service is offered on an HOV lane, riders using this service should also be surveyed.
- **Recruiting and Training Surveyors**. Available transit agency personnel, university students, employees of market research firms, or other individuals may be recruited to conduct the surveys. Surveyors should be polite, friendly, and reliable. Training should include reviewing the purpose of the surveys, the exact procedures for distributing and collecting the questionnaires, and specific assignments. Role playing is a good way to help surveyors develop proper techniques for approaching passengers and responding to riders who decline surveys.

Conducting Successful On-Board Ridership Surveys

Based on experience the following tips can help ensure conducting successful on-board ridership survey.

- **Survey Personnel**. The personnel conducting the survey are key. Personnel should be friendly, polite, and prepared. Survey staff should be trained in the proper procedures for conducting surveys. Personnel should dress professionally and have a name badge or other identification.
- **Come Prepared – Survey Assignment Bags**. The use of survey assignment bags are a great way for personnel to have everything they need at the survey site. Items in the bags should include the survey forms in packages of a set number, golf pencils, extra pencils with erasers, surveyor badge or identification, customer service cards, return survey boxes, clip boards, assignment sheets, and trip logs. The assignment sheet contains all the information the surveyor will need on starting time and location, buses to survey, and ending time and location.

On-Board Survey in Houston

- **Communicate to All Personnel**. It is important that bus operators, bus dispatchers, on-street supervisors, security personnel, transit station attendants, and other individuals in the field have been notified of the dates and locations of the surveys.
- **Distributing and Collecting Surveys**. Surveyors should be polite and friendly when asking passengers to complete a survey. Explain the survey purpose and let passengers know the information they provide is important. If a passenger declines a survey or is unpleasant, just thank them and move on to the next passenger. If surveyors are riding the bus, they should collect completed surveys from passengers. Another approach is to have someone else collect the completed surveys at the destination. Still another approach is to use a mail back survey.
- **Follow-Up.** If any passenger requests additional information or asks a question, be sure the surveyor provides them with a customer service card or follows-up with any specific requests.

Surveys of Carpoolers and Vanpoolers

As with on-board ridership questionnaires, surveys of carpoolers and vanpoolers are important for obtaining information on mode choice, the influence of an HOV lane on changing modes, travel time savings and trip time reliability from the HOV lane, and socio-economic characteristics. Key elements in developing and conducting surveys of carpoolers and vanpoolers include designing the survey and administering the survey. A mail out/mail back survey procedure is typically used with carpoolers and vanpoolers.

The carpool and vanpool questionnaire should be similar to the on-board survey to allow comparisons across modes. While there will be some unique questions, such as carpool formation and carpool members, the same basic questions related to trip purpose, trip origin and destination, travel time savings, importance of the HOV lane in the decision to carpool, and socio-economic characteristics should be included. While mail out surveys are typically used with carpoolers and vanpoolers, allowing more time to complete the questions, it is still suggested that a simple one-page format be used. The questionnaire used to obtain information from carpoolers and vanpoolers using the HOV lanes in Houston is provided in Figure 5.12.

A common procedure for conducting surveys of carpool and vanpool drivers is to record on video the license plate numbers of vehicles traveling in the HOV lanes for a specified period of time, usually the morning peak period. The license plate numbers are then transcribed by individuals watching the video in the office. The license plate numbers are transmitted to the state department of motor vehicles and a listing of vehicle owners is provided from the motor vehicle registration files. Typically, this list is reviewed, and out of state, rental car company, and business addresses are deleted. Addresses from other parts of the state may also be removed. The questionnaire, with a cover letter explaining the purpose of the survey and requesting the individual to complete it and return it in the postage-paid return envelope, is mailed to the remaining addresses on the list.

The experience with mail out/mail back surveys of HOV lane carpool and vanpool drivers has generally been good. For example, the response rate on surveys conducted in Houston over the years has averaged around 39 percent to 45 percent.

Other approaches that are sometimes used with these user groups include handing surveys directly to carpool and vanpool drivers as they enter or exit an HOV lane or park-and-ride/park-and-pool lot. The completed surveys are mailed back in the postage-paid return envelope provided. Concerns about safety and disrupting the operation of a facility may arise with this approach, but it may be appropriate in some areas if the right set of conditions exist. Other techniques include recording license plate numbers of cars parked at park-and-pool lots and mailing surveys to these individuals or intercepting carpoolers and vanpoolers as they are forming rides in lots. More information on intercept surveys is provided later in this section.

Undertaken by the Texas Transportation Institute, The Texas A&M University System in cooperation with the Texas Department Transportation, the Metropolitan Transit Authority of Harris County, and the U. S. Department of Transportation.

1. Is your vehicle a carpool or a vanpool? ___ Carpool ___ Vanpool

2. What is the primary purpose of your a.m. carpool/vanpool trip? ___ Work ___ School ___ Other

3. How many members are regularly in your carpool/vanpool (including yourself)? _

4. Who makes up your carpool/vanpool group? ___ Family Members ___ Neighborhood Friends ___ Co-Workers

5. Does your carpool/vanpool use a park-and-ride or park-and-pool lot as a staging area?
___ Yes (please specify which lot you typically use ______________________) ___ No

6. Does your carpool/vanpool use the Sam Houston Tollway? ___ Yes ___ No

7. How long have you been a regular use of the North HOV lane? ______

8. Which HOV lane entrance to you normally use to access the North HOV lane in the morning?
___ North Belt mainlane entrance ramp ___ Aldine-Bender wishbone ramp ___ North Shepherd ramp

9. What time do you normally enter the HOV lane in the morning? ____________ a.m.

10. What is your a.m. carpool/vanpool destination? ___ Downtown ___Galleria/City Post Oak/Uptown
___ Texas Medical Center ___ Greenway Plaza ___ Other (specify Zip Code ___________)

11. When did you join your present carpool/vanpool? Month: __________ Year: ____________

12. How important was the North HOV lane in your decision to carpool/vanpool?
___ Very Important ___ Somewhat Important ___ Not Important

13. If the North HOV lane had not opened to carpools/vanpools, would you be carpooling/vanpooling now?
___ Yes ___ No ___ Not sure

14. Prior to carpooling/vanpooling on the North HOV lane, how did you normally make this trip?
___ On the HOV lane
___ Bus ___ Vanpool ___ Carpool
___ On the North Freeway general-purpose lanes
___ Bus ___ Vanpool ___ Carpool ___ Drove Alone
___ On a parallel street or highway (Street Name _______________________)
___ Bus ___ Vanpool ___ Carpool ___ Drove Alone
___ Did not make this trip

15. How many minutes, if any, do you believe your carpool/vanpool saves by using the North HOV lane instead of the regular traffic lanes?
Minutes in the morning _______ Minutes in the evening

16. Do you feel that the North HOV lane is, as present, sufficiently utilized to justify the project?
___ Yes ___ No ___ Not sure

17. 1. What is your... Age? _____ Sex? _____ Occupation? _____________________

18. What is the last level of school you have completed? ________________

19. What is your home Zip Code? __________________

Figure 5.12. HOV Lane Carpool and Vanpool Survey – I-45 North, Houston.

Intercept Surveys

Intercept surveys provide another method that may be used to obtain information from bus riders, carpoolers, vanpoolers, and other exempt vehicle user groups. As the name implies, intercept surveys involve meeting or intercepting individuals at specific locations. Intercept surveys provide the opportunity to obtain more information on specific groups than might otherwise occur through random-sample telephone or mail surveys. Intercept surveys may also be used to randomly collect information from larger population groups. Individuals may be approached as they are walking, waiting at specific locations, riding on transit vehicles, or traveling in their personal vehicles. Agency staff or contract surveyors approach individuals and either asks them to fill out a survey or conduct a brief interview with them.

Intercept surveys may be used to target a specific user group. As noted in the case study examples, intercept surveys have been used to obtain information from casual carpoolers in Houston, and from carpoolers and bus riders on the I-15 HOV lanes in San Diego.

Intercept surveys provide an advantage in collecting information on small, non-random populations that would be difficult to reach cost-effectively through telephone or mail surveys of the general population. An inherent limitation with this technique if small sample sizes and non-random selections processes are used is that the results are not statistically reflective of all members of the target group. Another limitation of intercept surveys is that given the short duration of time individuals be available at a specific location, surveys must be kept brief focusing on a few key questions.

Survey of Casual Carpoolers – Houston

A survey of casual carpoolers at two park-and-ride lots on the I-10 West HOV lane and one park-and-ride lot on the US 290 HOV lane was conducted in 2003 as part of the Houston QuickRide project. Casual carpoolers waiting for rides at these locations were approached by survey personnel and asked if they would complete a survey and mail it back.

A total of 578 casual carpoolers were approached and 538 individuals agreed to take the survey, accounting for a seven percent refusal rate. Of the 538 casual carpoolers taking the survey, 216 completed surveys were returned, for a response rate of 40 percent. The survey included questions on frequency of casual carpool use, reasons for casual carpooling, mode of travel in the afternoon, and socio-economic characteristics.

I-15 Value Pricing Intercept Surveys – San Diego Association of Governments

The San Diego Association of Governments (SANDAG) and Caltrans used focus groups, stakeholder interviews, intercept surveys, and a telephone survey in a two-year study examining the potential of expanding the future I-15 managed lanes.

The results from these activities were used to assist in developing the proposed project elements and to ensure that potential environmental justice issues were addressed. The various tasks were conducted by market research firms as part of the consulting team assisting with the overall I-15 Managed Lanes Value Pricing Project Planning Study.

The intercept surveys were conducted to obtain information from transit riders and carpoolers in the I-15 corridor. Given the small size of the sample and the non-random selection process, the results are not statistically reflective of all carpoolers and transit riders in the area. The results do provide insights into the reactions of these groups of commuters to the proposed elements of the project.

A total of 50 transit riders were surveyed at two bus stops associated with park-and-ride lots in the corridor. There were 26 riders surveyed at one location and 24 passengers were surveyed at the second location. The surveys were conducted in the morning peak period, as riders waited for buses traveling into downtown San Diego. The outreach team staff approached riders. The project was quickly described and individuals were asked to complete the short survey, which was designed to be completed in a few minutes.

Carpoolers were surveyed at the park-and-ride lot located at the northern end of the I-15 Express Lanes. Team members set up a table with the surveys. Morning snacks and beverages were also available to help encourage participation. Since most commuters drive alone and wait in their vehicles for their carpool partners to arrive, team members modified their technique and approached arriving vehicles. The project was explained and drivers were asked to complete the survey. Depending on the driver's preference, the surveys were either filled out by the driver or the team member. The carpool surveys were slightly longer than those used with bus riders as there was more time for responses.

Surveys of General-Purpose Lane Motorists

Surveys of motorists in the freeway general-purpose lanes may be conducted as part of an HOV performance monitoring program. Motorist surveys are used to obtain information on perceptions related to HOV lane use, reasons for not using the HOV lane, and socio-economic characteristics. Although there will be some unique questions, these surveys should follow the same general format as the on-board, carpool, and vanpool surveys to allow for comparisons across modes. A one-page format is suggested and mail out/mail back process is typically used.

Figure 5.13 highlights the questionnaire used in Houston. The survey conducted in Los Angeles is highlighted in the case study. A procedure similar to that used with vanpool and carpool surveys is frequently used. Personnel in the field video record license plate numbers of vehicles traveling in the mixed-traffic lanes. Surveys are mailed to the appropriate addresses provided by the department of motor vehicles with a postage-paid return envelope. Response rates are usually fairly good. In a 1998 survey conducted on the I-10 West Freeway mainlanes, approximately 4,800 license plates were recorded. Out of this total, approximately 3,100 surveys were mailed. A total of 1,050 completed surveys were returned, accounting for a 37 percent response rate.

Motorist Survey – LAMTA

A survey was conducted of peak-hour freeway commuters in both the freeway lanes and the HOV lanes in 2001 as part of the LAMTA Performance Monitoring Program. Motorists traveling on freeways without HOV lanes were also included in the survey. License plates of vehicles traveling on the various freeways were video taped and surveys were mailed to the addresses received from the California Department of Motor Vehicles. The surveys were in both English and Spanish and a postage-paid return address envelope was provided. A total of 31,751 surveys were mailed, and 6,178 surveys were returned for a response rate of 19 percent. The surveys covered 16 freeways with HOV lanes and seven freeways without HOV lanes. The number of responses in each freeway corridor provided statistically significant results that were examined at both the corridor level and county wide.

Undertaken by the Texas Transportation Institute, The Texas A&M University System in cooperation with the Texas Department of Transportation, the Metropolitan Transit Authority of Harris County, and the U. S. Department of Transportation.

1. What was the purpose of your trip? _____ Work _____ School _____ Other

2. What are your reasons for driving your car on the freeway mainlanes rather than traveling in a high-occupancy vehicle on the HOV lane?
   _____ Need car for job _____ Car is more convenient and flexible
   _____ No convenient bus, vanpool, or carpool available _____ Work irregular hours
   _____ Other (Specify ____)

3. How many days per week do you normally make this trip?

4. How do you usually make this trip? _______ Drive alone ___ Vanpool ___ METRO regular route or express bus _____Carpool __________ METRO park-and-ride bus ___ Other (specify________)

5. How many people (including yourself) were in your vehicle for this trip?

6. Which on-ramp did you use to enter the North Freeway for this trip?

7. What was the destination of your trip? ___ Downtown ___Galleria/City Post Oak/Uptown
   ___ Texas Medical Center ___ Greenway Plaza ___ Other (specify Zip Code ___________)

8. Based on your observation of the number of vehicles currently using the North HOV lane, do you feel that it is being sufficiently utilized? ___ Yes ___ No ___ Not sure

9. Based on your perception of the number of persons currently being moved on the North HOV lane, do you feel that it is being sufficiently utilized? ___ Yes ___ No ___ Not sure

10. Do you feel that the North HOV lane is a good transportation improvement?
    ___ Yes ___ No ___ Not sure

11. Do you normally listen to traffic reports on the radio at home, at work, or in your car? ___ Yes ___ No
    If "yes," have you every changed your original travel plans (taken an alternate travel route, altered your travel time, or used a bus or carpool) because of information obtained from these reports? ___ Yes ___ No

12. Do you know the location of the park-and-ride lot nearest your home? ___ Yes ___ No ___ Not sure

13. Do you know enough about the park-and-ride service provide by METRO to confidently begin using it tomorrow?
    ___ Yes ___ No ___ Not sure

14. What is your... Age? _____ Sex? _____ Occupation? ______________________________

15. What is the last level of school you have completed? _______

16. What is your home Zip Code? ______________

Figure 5.13. General-Purpose Motorist Survey – I-45 North, Houston.

Surveys of the General Public

Telephone or mail surveys may sometimes be conducted of the general public as part of an HOV monitoring program. Surveys of the general public may be undertaken to gauge general perceptions related to HOV facilities, traffic congestion, and transportation improvements. Given the time and expense associated with these types of surveys, they are not used extensively, however. A more cost-effective method to obtain information from the general public would be to add questions on HOV-related topics to regular surveys frequently conducted by different groups in many metropolitan areas.

General Public Telephone Survey – LAMTA

A random sample telephone survey of Los Angeles residents was conducted as part of the LAMTA HOV Performance Monitoring Program. The survey focused on questions relating to perceptions about traffic congestion and preferred solutions, use of and attitudes about the HOV lanes, and commuting patterns. Information was also obtained on carpooling characteristics and behavior, factors influencing carpool mode choice, reactions toward different carpool policies, and demographic characteristics of respondents.

The survey was conducted by a market research firm. A total of 3,273 surveys were completed. The sample was distributed across nine subregions in the county in proportion to the population. The survey sample was also balanced to match gender, age, ethnicity, and income of county residents. The surveys were conducted in both English and Spanish. Random digital dialing was used to obtain telephone numbers. The surveys were conducted Monday through Friday from 6:00 p.m. to 9:00 p.m. and weekend days from 9:00 a.m. to 9:00 p.m.

Focus Groups

Focus groups are a qualitative market research technique used to obtain information on a topic and to provide insight into how people feel about a particular subject. This approach does not provide quantitative information because the number of participants is too small to be representative of the population as a whole.

Focus groups usually consist of 8 to 12 people. Participants are selected either to represent a certain type of consumers, or randomly to assure broad representation. Focus groups typically last about two hours, and participants are often paid or given some incentive to participate. Focus groups are led by a professional facilitator or discussion leader using a series of scripted questions to help ensure that the key topics are covered and that the same approach is used with multiple groups. Interaction among group members is encouraged.

Visual and audio aids may be used or participants may be asked to respond to different transportation modes, design approaches, or slogans and messages. Focus groups are a relatively inexpensive and efficient approach to obtaining preliminary information and responses to topics and issues. A focus group can be conducted and findings reported in less than two weeks time. The focus group can be used to gauge public opinion and explore alternatives by identifying a customer's needs, expectations, and concerns.

Focus groups may be used as part of an HOV performance monitoring program, or more typically, as part of an HOV market research effort. Focus groups have been used on the I-394 HOV lanes in Minneapolis, in the development of the QuickRide project in Houston, and the extension of the I-15 HOV lanes in San Diego.

I-393 HOV Lanes – Minneapolis

The Minnesota Department of Transportation (Mn/DOT) used focus groups in the development of the marketing and public information strategies on the I-394 HOV project. Focus groups, comprised of residents and commuters in the corridor, were used to test different marketing slogans, newspaper advertisements, and radio jingles for the interim HOV lane. The focus groups were conducted by a marketing firm under the direction of a multi-agency team headed by Mn/DOT.

Stakeholder Interviews

Interviews may be conducted with key stakeholders as part of an HOV performance monitoring program. Key stakeholders may include members of the state legislature, local elected officials, agency executives, business representatives, and special interest group representatives. These interviews provide the opportunity to obtain opinions, thoughts, ideas, suggestions, and issues from key individuals. They also provide the opportunity to provide stakeholders with information on the performance of HOV facilities.

Executive Interviews – LAMTA

Interviews were conducted with a selected group of key stakeholders as part of the LAMTA HOV Performance Monitoring Program. A total of 13 interviews were completed in 2000 and 2001 with elected officials, private sector transportation providers, and public transportation agency personnel. The one-on-one interviews were conducted in the stakeholders' office by a transportation consultant. Participants were asked a set series of questions related to HOV facilities in the county. Given the small number of interviews, the results were not statistically significant, nor could they be used to project preferences for the larger groups the participants represented. The results were of benefit in identifying opinions, opportunities, and issues related to the HOV facilities in the county by some key stakeholders.

On-Line Surveys

On-line surveys involve using the Internet to post questionnaires for individuals to complete. With the widespread application of agency Internet sites and Internet use by the public, on-line surveys represent a growing market research technique. Different approaches may be used with on-line surveys, and they may be used in conjunction with telephone or mail surveys to increase participation levels.

One possible approach is to post a survey on an agency Internet site and solicit responses from all elements of the population. This technique, which has been used to obtain input on long-range transportation plans and other programs, may provide a large response. Use of the results must consider the self solicitation issue, however, and the results should not be transferred to the population as a whole. Although the use of computers and the Internet is widespread today, there are segments of the population that do not have access. Thus, from an environmental justice perspective some groups may be underrepresented in on-line surveys.

A second approach with on-line surveys is to target a specific user group or segment of the population. This method has been used to survey participants in demonstration projects and members of certain groups. Typically, an e-mail is sent to members of the target group requesting their participation in the survey and directing them to the survey site. This approach was used as part of the evaluation of one element of the Seattle Smart Traveler demonstration, with e-mail surveys sent to individuals who had registered for the dynamic carpooling demonstration at the University of Washington.

On-line surveys may be developed and implemented by agency staff. Consulting firms and universities may also provide assistance with on-line survey techniques. Some transportation agencies use firms specializing in the development of Internet sites and on-line surveys.

To date, on-line surveys have not been used extensively with HOV performance monitoring programs. This technique may be appropriate for further consideration, however, especially to reach specific user groups, such as individuals who have purchased transponders as part of a HOT project or other groups with known e-mail addresses.

Crash Data

Crash data should be monitored on the HOV lanes, in the adjacent freeway general-purpose lanes, and on the control freeways. In most areas, crash information is obtained from the state department of transportation, the local department of public safety, and the state, local, or transit police.

Ensuring that similar techniques are used to collect and analyze accident data is important. For example, variations may exist in the methods used to record accidents by different agencies in the same corridor. Further, it is often difficult to determine the exact cause of an accident and the exact location. Establishing a methodology in the study design that all groups responsible for accident records agree to use and developing a good trend line before an HOV facility is opened are two important steps to ensuring accurate accident data.

Crash Data Needs

In examining crash data associated with an HOV facility and the adjacent general-purpose lanes, the following items should be collected, examined, and included in the HOV crash data base.

- **Mile Point/Physical Location**. The actual location along the HOV lane or freeway of the crash is needed. The crash location may be included in a GIS database or map.
- **Lane Where Crash Occurred**. Information is needed on the lane where the crash occurred. The lane the vehicles ended up in may be different from where the crash started, so it is important to obtain the other information noted below to fully understand the factors influencing a crash.
- **Type of Crash**. Information is needed on the type of crash, such as rear-end, side-swipe, and single-vehicle off the road.
- **Severity of the Crash**. Information is needed on the severity of the crash. Classifications typically include fatality, incapacitating, non-incapacitating, and possible injury.
- **Day of the Week**. The day of the week the crash occurred should be included in the database.
- **Time-of-Day**. The time the crash occurred should be included in the database.
- **Weather and Roadway Conditions**. The weather conditions at the time of the crash should be recorded, along with any impact the weather had on roadway conditions, such as wet pavement.
- **Driver Condition**. Any available information on the condition of the driver, such as driving while intoxicated, should be included in the database.
- **Narrative and Diagram**. Any narratives or diagrams provided by the police should be reviewed and included in the database.

Crash Data – Houston HOV Lanes

The METRO police are responsible for responding to crashes occurring in the six Houston barrier-separated HOV lanes. METRO police are also responsible for documenting the crashes and maintaining the crash records. The METRO crash data table includes the date, time, and location of the crash. It also includes the damage rating, comments, the driver's age range, and the type of ticket issued. The damage rating classifies crash damage as major or minor, indicates the number and types of vehicles involved, and notes if fixed objectives were hit. The comment section provides a brief description of how the crash occurred. Information from the METRO police records is included in the quarterly reports. For each corridor the number of crashes is listed. The crash rate, which is the number of crashes per 100,000 vehicle trips, is also calculated and provided in the quarterly reports.

Violation Rates

The violation rates, which reflect the number of vehicles not meeting the minimum HOV lane occupancy requirements, can provide a general indication of the degree of public understanding and support for the facility and if the facility is being used for the intended purpose. Violation rates are typically monitored in two different ways. First, information on the number of citations issued should be obtained from the agency responsible for enforcing the HOV lanes. The state, local, or transit police are typically responsible for issuing citations for violation of vehicle-occupancy requirements or other moving violations. Second, the vehicle and occupancy counts also provide information on the number of vehicles, by time-of-day, not meeting the minimum occupancy requirements. The results from both of these sources are examined as part of the ongoing monitoring and evaluation process. Some areas have experimented with the use of video cameras to monitor occupancy levels and violations of the occupancy requirements. Current technologies appear to have a number of limitations preventing their use at this time. As new technologies are developed, however, video cameras or other approaches may be appropriate for use in monitoring HOV lane violation rates and related enforcement activities.

Areas with peer-enforcement programs, such as the HERO program in Seattle, also monitor the number of calls received to the HERO hotline. The total number of calls is monitored, as is the number of repeat license plates of vehicles reported as violating the HOV occupancy requirements.

Information Relating To Vehicle Emissions, Air Quality, and Energy Consumption

As HOV lanes carry more people in fewer vehicles, it is generally thought that HOV facilities have a positive influence on air quality, vehicle emissions, and energy consumption. This issue has been debated, however, and no comprehensive assessment has been conducted to date.

Unless specific air quality monitoring is conducted along an HOV facility, the typical approach to examine possible environmental benefits is to estimate the potential impacts with and without the HOV lanes. The input data needed for most models or estimation procedures include vehicle volumes, vehicle-occupancy levels, and vehicle speeds. Models and techniques for estimating possible environmental impacts are discussed in the next chapter.

Summary

The data collection techniques typically associated with HOV performance monitoring programs are discussed in this chapter. The data collection methods and the frequency of data collection activities will be influenced by a number of factors. These factors include the number of HOV lanes in an area, the types of HOV lanes, the operating hours, and the number of years the HOV lanes have been in operation. The availability of data from other sources, and available staff and financial resources will also influence the data collection process.

Developing and conducting ongoing data collection and monitoring programs are described in Chapter Seven. At a basic level, it is suggested that data on vehicle classification, vehicle-occupancy, and travel time be collected for the HOV lane and the general-purpose freeway lanes on a regular basis. Data should be collected before an HOV lane is opened for the general-purpose freeway lanes. During the initial phase of a project, quarterly data collection should be considered. Over time, annual data collection may be appropriate. Collecting crash data, conducting surveys of users and non-users, and monitoring enforcement are also important based on available funding.

CHAPTER SIX – DATA REDUCTION AND ANALYSIS TECHNIQUES

Chapter-at-a-Glance

This chapter describes elements to consider in archiving, storing, and managing data collected in HOV performance monitoring programs. Data reduction and processing, including methods to address potential data quality control issues, are highlighted. Data analysis techniques frequently used with HOV objectives and measures of effectiveness are presented.

- **Data Archiving, Storage, and Management**. This section describes elements to consider in developing a process to archive, store, and manage the data collected in an HOV performance monitoring program.
- **Data Reduction and Processing**. This section highlights elements to consider in transferring data collected in the field or electronically into databases and software programs for further analysis. The importance of data quality control is discussed, and methods to ensure data accuracy and integrity are presented.
- **Data Analysis Techniques**. This section highlights the data analysis techniques and calculations associated with the measures of effectiveness described in Chapter Four.

Data Archiving, Storage, and Management

To use the data collected through the methods described in the previous chapter, a process must be established for archiving, storing, and managing the data. It is important that this process be well thought out and documented prior to initiating actual data collection activities. These procedures will guide the data reduction process described in the next section.

The data collection methods will influence the data archiving, storage, and management process. The archiving and retention process for data collected through actual field monitoring and observations is different from the process used with data obtained from advanced transportation management systems, which typically requires increased computer capabilities. Key elements to consider in establishing data archiving, storage, and retention programs are highlighted below. These steps include establishing a lead agency, establishing the actual procedures, identifying funding sources, and establishing procedures for accessing and using the data. More detailed information on this topic, especially related to the use of archived data from advanced transportation management systems, is available in the references listed in Appendix A.

- **Establish Lead Agency.** The first step is to identify the lead agency responsible for data archiving, storage, and retention. The lead agency is typically the agency responsible for operating the HOV facility and conducting the HOV performance monitoring program. As noted previously, the state department of transportation is frequently the lead agency for all these activities. In some cases, state departments of transportation or other operating agencies have contracted with university-affiliated transportation research groups or consultants to provide that data archiving, storage, and retention functions.

- **Establish Procedures for Data Archiving, Storage, and Management**. This step develops the actual procedures for archiving, storing, and managing data from HOV performance monitoring programs. As noted previously, the data collection methods will influence this process. Data collected specifically from field observations will typically need to be reentered or downloaded into spreadsheets or databases. Data obtained from advanced transportation management systems is usually transferred electronically and may require additional computer resources and data manipulation. In either case, the protocol for transferring data, and the software programs, computers, and other support elements to be used will all need to be determined. The National ITS Architecture and ITS/ADVS standard (ASTM E2249-03) provides guidance on archiving data obtained from advanced transportation management systems.
- **Identify Funding Sources**. An important step in developing procedures for HOV data archiving, storage, and management is identifying potential funding sources and developing a maintenance plan. In many cases, the data may be collected for other operational applications. However, the management of incoming data and data reporting processes will still require operating/maintenance costs. While the lead agency may provide most of the needed funding, other agencies using the data may share in the costs. Potential funding sources for HOV performance monitoring programs, including data archiving, are discussed in Chapter Seven.
- **Establish Procedures for Accessing and Using Data**. Procedures should be established to guide access and use of the data by agencies and other groups. Elements to consider in developing these procedures include who will have access, how access will be provided and monitored, and any limitation on use of the data.

Data Reduction and Processing

Data collected in the field or through advanced transportation management systems using the methods described in the previous chapter must be transferred into databases and other software programs for further analysis. Based on the data archiving, storage, and management process, standard procedures should be established and used to transfer data collected in the field or obtained from other sources. These procedures should ensure the integrity and accuracy of the data. The data collection methods used will influence the data reduction process. This section highlights the commonly used methods for reducing and processing HOV performance data. It also discusses data quality control issues and methods to help ensure data accuracy and integrity.

The data collected by the field crews on vehicle volumes, vehicle classification, vehicle-occupancy, travel times, and other measures are usually transferred to office personnel for processing and analysis. Data collected using a manual device and a count form will need to be manually entered into a spreadsheet or database. Data are typically entered by the specific time periods when the counts were taken. Data collected using computers or other electronic devices are downloaded or transferred into a central computer or database. Data obtained through advanced transportation management systems may be transferred from one computer system to another.

The databases or files are typically maintained by corridor or freeway facility. The databases or files for the HOV facility and the general-purpose freeway lanes are also usually maintained separately, as are the files for each vehicle classification and the respective occupancy counts. This process allows for calculations by the different vehicle classes and aggregating the total volumes and occupancy levels.

Quality control is critical to ensuring the accuracy and integrity of the data. The database or spreadsheet files should be checked before any analysis is conducted. The following items should be considered as part of a data quality control program. Data should not be used if there are significant concerns related to accuracy or quality.

> The accuracy and integrity of data collected as part of an HOV performance monitoring program is critical. Elements in a data quality control program include checking to ensure data are entered and transferred correctly, establishing and applying validity checks to identify suspect or invalid data, reviewing comments from field crews or data collection logs, and identifying and correcting any problems at specific manual or automatic data collection sites.

- **Check to Ensure Data Entered Correctly**. If field data are re-entered or downloaded, quality checks should be made to ensure the data are entered into the correct files and that no errors have occurred in the transfer. For example, checks should be made to ensure the file headings match the count locations, time periods, that the data collection times are entered correctly, and that individual data entries are correct.
- **Establish and Apply Quality Control or Validity Checks**. Quality control or validity checks can be performed manually or can be automated to identify suspect or invalid data values. Quality control typically includes identifying parameters for each data category. Data with values outside these parameters, frequently called outliers, can be flagged. The suspect or invalid data can be reviewed by staff and a determination made to include or exclude it from the database and further analysis. Factors used to establish the parameters or business rules typically include established

traffic flow and capacity principles, expected ranges and rules of thumb, and anticipated changes and deviations.

- **Comments from Field Crews or Data Collection Logs**. Comments provided by data collection field crews should be reviewed to identify any possible occurrences that might have influenced traffic conditions during the data collection periods. Examples of occurrences that may impact normal traffic patterns include weather (rain, snow, sleet) and major incidents or crashes. If archived data from advanced transportation management systems are used, a log may be maintained with the same type of information.
- **Improve Data Quality at the Source**. The quality control checks can also be used to identify potential problems at a specific data collection site – either a manual count location or an electronic sensor location. Data sites with repeated quality issues should be checked and problems should be addressed as needed.

Data Analysis Techniques

This section highlights the data analysis techniques and calculations typically used with the measures of effectiveness discussed in Chapter Four. A brief description of each analysis technique is provided, with formulas presented as appropriate. Examples of using many of these analysis techniques are presented in the case studies in Chapter Nine.

Vehicle Volumes

Vehicles volumes for the HOV lane and the general-purpose freeway lanes are presented for the specific points along the corridor where the data is collected. The vehicle volumes are typically summarized for the morning and afternoon peak hours and peak-periods. A 24-hour count may also be provided if the HOV lanes operate on a 24/7 basis. Vehicle volumes per hour per lane are typically reported for the HOV lane and the general-purpose freeway lanes. For the freeway, the number of vehicles using the freeway is divided by the number of lanes to obtain the vehicle volume per hour per lane. Vehicle volumes in the HOV lanes are typically reported over time. Experience indicates that use levels grow after the opening of a facility, but may reach a relatively stable condition after three-to-five years of operation.

Person Volumes and Person Throughput

Person volumes are the total number of individuals in all vehicles at the specific data collection points for a specific time period. Person volumes may be presented as the persons per hour per lane (pphpl). The pphpl for the morning and afternoon perk hour is calculated by totaling the number of individuals in all vehicles for the specific hour in the HOV lane. The same calculation is performed for the freeway general-purpose lanes. Person volumes for the HOV lane and the general-purpose freeway lanes are presented for the same data collection locations during the same time periods as the vehicle volumes. A comparison is typically made of the person volumes, pphpl, or person throughput on the HOV facility versus the general-purpose freeway lanes. The total person throughput for the facility can also be computed by combining the HOV and general-purpose freeway lanes together.

Average Vehicle-Occupancy

Average vehicle-occupancy (AVO) is calculated from the vehicle volume by classification and person throughput data. AVO by vehicle classification, total AVO for the HOV lane, total AVO for the freeway, and total AVO for the facility (HOV and freeway) can be calculated. AVO by vehicle classification is obtained by dividing the person throughput for a specific vehicle type by the number of vehicles in that classification. The calculation is typically made for the HOV lane and the general-purpose freeway lanes separately for same time periods noted previously – peak hours, peak-period, and 24 hour basis. The total AVO for the HOV lane or the general-purpose freeway lanes is calculated by adding the total occupancy for all vehicles divided by the total vehicles. The AVO in the HOV lanes is compared to the AVO in the general-purpose freeway lanes. A total facility AVO can be calculated by dividing the total person volume for both the HOV and general-purpose freeway lanes by the total vehicle volumes. The AVO is usually carried out to the hundredth of a decimal point (i.e., 1.24).

Travel Times and Travel Speeds

The method for calculating travel times and travel speeds will depend on the data collection technique used. Travel time data collected electronically using the floating car technique is usually processed through a software program that calculates travel time and travel speed and transfers the results to a spreadsheet or database. Travel times collected manually using the floating car technique are manually entered into a spreadsheet or database which is then entered into the software program. Travel time and travel speed data for multiple runs can be averaged and reported for the HOV lane and the general-purpose freeway lanes. Data obtained through advanced transportation management systems typically provides speed data for the HOV lane and the general-purpose freeway lanes. Software programs are used to estimate travel times from the speed data. As noted below, the results from the HOV lanes and the general-purpose freeway lanes can be compared to obtain the travel time savings provided by the use of the HOV lane.

In addition, average trip travel times may be calculated and presented by trip start time. This approach provides an indication of travel times in the HOV lane and general-purpose freeway lanes during different times of the day that match work, school, recreation, and other trip purposes.

Travel Time Savings

Travel time savings measure the amount of time a traveler saves by using the HOV lane rather than the general-purpose freeway lanes for the same trip distance. Travel time savings are calculated by taking the difference in travel times between the

HOV and the general-purpose freeway lanes. It is typically presented as the number of minutes saved by vehicles in the HOV lane for a specific trip distance, usually the length of the HOV lane. For example if it takes 30 minutes to travel from point A to point B in the general-purpose freeway lanes and 24 minutes to travel the same distance in the HOV lane, the travel time savings from the HOV lane is 6 minutes.

Travel Time Index

The travel time index is a comparison between the travel conditions in the peak period and travel conditions in freeflow periods. The travel time index formula in Figure 6.1 can be used to provide a travel time index for a freeway or an HOV lane. For example, a value of 1.20 indicates that the travel time during the peak period is 20 percent longer than the travel time during the off-peak period. More complex formulas can be used to develop a travel time index for a corridor or an urban area. The references listed in Appendix A provide sources for more information on developing and using the travel time index measure.

$$\text{Travel Time Index} = \frac{\text{Average Peak Period Travel Time}}{\text{Average Off-Peak Travel Time}}$$

Figure 6.1. Formula for Travel Time Index.

Trip Time Reliability

As noted previously, typical objectives of HOV lanes relate to providing travel time savings and improved trip time reliability to carpoolers, vanpoolers, and bus riders using the lanes. Trip time reliability can be defined as the consistency or the dependability in travel times, as measures from day-to-day and/or across different times of the day. The development of analytical techniques to measure trip time reliability is an emerging practice. Presented next are two measures of reliability – the buffer index and travel speed reliability.

Buffer Index

The Buffer Index, shown in Figure 6.2, is a measure of trip reliability. It expresses the amount of extra time or the “buffer” needed to be on-time for 95 percent of trips made during a certain time, such as the peak period. The 95 percent measure would amount to being late for work or school one day per month. Indexing the measure provides a time and distance neutral measure. The actual minute values could be used by an individual traveler for a particular trip length, however. Appendix A presents more detailed descriptions of the buffer index.

$$\text{Buffer Index} = \frac{\text{95th Percentile Travel Time - Average Travel Time}}{\text{Average Travel Time}}$$

Figure 6.2. Formula for Buffer Index.

Travel Speed Reliability

Trip speed reliability provides another possible measure of trip time reliability. A commonly used travel speed reliability measure is the percent of time that travel speeds fall below an average speed of 45 mph. The 45 mph criteria equates to a Level of Service (LOS) C for a posted speed limit of 55 mph. Using this measure, travel speed reliability can be assessed for an HOV lane and for the adjacent general-purpose freeway lanes over the same time period, typically the peak hours. Use of this measure is dependent on data available from advanced transportation management systems due to the volume and frequency of travel speeds needed. Data obtained from annual or periodic travel time runs does not adequately capture the day-to-day differences in travel speeds needed for this measure.

Another approach focuses on identifying the frequency of heavy congestion in the HOV lane and general-purpose freeway lanes. For example, the percentage of days that the average overall trip speed for a certain trip start time falls below a certain level, such as 35 mph, can be calculated. A frequency of 50 percent for trips starting at 7:00 a.m. would indicate that 50 percent of the time a 7:00 a.m. trip would have an overall average speed of less than 35 mph. The use of this approach requires data from an advanced transportation management system.

Transit Vehicles and Ridership

Information on the number of buses using an HOV facility and ridership levels is usually presented numerically and as a percentage of the total vehicles and persons using the facility. This information is typically analyzed for the morning and afternoon peak hours and the peak-periods. Information on off-peak levels may also be provided if bus services are operated during these time periods. In addition, maintaining maps illustrating the bus routes using the HOV lanes is recommended as they provide an excellent way to highlight service improvements and expanded service coverage.

Transit vehicles and passengers may also be presented as the AVO for transit and as part of total AVO for the HOV facility. The transit AVO is obtained by dividing the total bus ridership by the number of buses for a specific time period. The total AVO for the HOV facility is calculated by adding the number of persons in all vehicles and dividing by the total number of vehicles. The percentage buses and bus riders that comprise the total vehicle and person volumes in the lane can also be calculated by dividing the number of buses and bus riders by the total number of vehicles and persons.

Park-and-Ride and Park-and-Pool Lot Use

Data on park-and-ride and park-and-pool lot use is presented both as the actual number of vehicles parked at a lot and the percentage of lot utilization. The percent of lot utilization is calculated by dividing the number of parked vehicles by the total number of available parking spaces. The total number of vehicles parked at all lots along an HOV corridor and the total utilization for all lots is also usually presented.

Occupancy Violation Rates

The vehicle-occupancy violation rate, which is typically referred to as the violation rate, measures the number of non-exempt vehicles in the HOV lane not meeting the occupancy requirement. This information is obtained through the vehicle-occupancy counts. Single-occupant vehicles on an HOV lane with a 2+ requirement would be considered violators, unless they are exempt vehicles. Violators on an HOV facility with a 3+ requirement would include two-person and single-occupant vehicles, unless they are part of an exempt vehicle classification.

Violation levels on an HOV lane are usually expressed as a rate comparing the number of violators with the total vehicles in the lane. As shown in Figure 6.3, violation rates are expressed as a percentage by dividing the number of vehicles not meeting the occupancy requirement, excluding exempt vehicles, by the total number of vehicles in the lane.

$$\text{Percent of Violators} = \frac{\text{Number of Vehicles Not Meeting Occupancy Requirement}}{\text{Total Number of Vehicles in Lane}}$$

Figure 6.3. Formula for Calculating Vehicle-Occupancy Violation Rate.

Occupancy Violation Citations

The number of citations issued by enforcement personnel to drivers of vehicles not meeting occupancy requirements provides another measure of violation levels. The ability to issue citations is influenced by the presence and level of enforcement on a facility, which may vary over time. As a result, this measure is typically reported as the number of citations issued over a specific time period, with a reference to enforcement levels provided during the reporting periods.

Operating Violation Citations

The numbers of citations issued for violating operating requirements, such as entering or exiting an HOV lane illegally, are typically reported for specific time periods. Citations may be issued for moving violations or other infractions. As noted with citations for occupancy violations, the number of citations issued for operating requirements violations will be influenced by the level of enforcement. Examination of information on the number of operating regulation violations should include an assessment of enforcement levels during the different time periods.

HOT Violations

Non-payment of tolls with HOT projects is monitored by the operating agencies. The number of toll violators may be reported or the toll violation rate may be calculated by dividing the number of non-paying vehicles by the total number of HOT vehicles using the lane for the same time period. Figure 6.4 presents the formula for this calculation.

$$\text{Percent of HOT Violators} = \frac{\text{Non-Paying HOT Vehicles in Lane}}{\text{Total HOT Vehicles in Lane}}$$

Figure 6.4. Formula for Calculating HOT Violation Rate.

Crash Rates

Crash data is often summarized as the number of crashes related to vehicle miles of travel (VMT) or passenger miles of travel. Crash rates measure safety trends or crash potential related to vehicle exposure measured in VMT. Annual vehicle crash rates are calculated as vehicle crashes per 100 million VMT. It is recommended that crash rates be documented for a freeway before the HOV lane is implemented. Crash rates may be examined on an annual basis after the lane is open to try to identify the impact of an HOV lane. Given potential limitations with many crash databases, however, a lane-by-lane comparison is not usually possible, as crash rates are not typically lane-specific. A general comparison of the crash rates for freeways with HOV lanes to freeways without HOV lanes and to the state average may be appropriate.

Mapping the location of crashes in GIS can help identify potential problem spots. If crashes are clustered in similar areas, these locations can be examined for potential changes in operation or design modifications. Examining crash rates per million passenger miles of travel considers the difference in person throughput of the HOV lane and general-purpose freeway lanes. The crash rates per million passenger miles of travel for the HOV lane and the general-purpose freeway lanes are calculated and compared.

As noted previously, obtaining crash data at a level of detail needed to assess the impact of an HOV lane may be difficult and time consuming. The information provided in crash databases maintained by law enforcement, transportation, and public safety agencies may not be at the level of detail needed to determine the starting point of the crash, the ending point, and the potential influence of the HOV lane on the crash. This type of data may only be available by examining individual crash records, which is typically beyond the resources available for most HOV performance monitoring programs.

Vehicle Emissions and Air Quality

There continues to be debate among different groups about the impact of HOV lanes on vehicle emissions, air quality, and fuel consumption. By carrying more people in fewer vehicles, HOV facilities are generally considered to have a positive influence on air quality. There is no definite study on HOV lanes and air quality, however, and no one best method to analyze possible impacts.

The potential air quality impacts associated with HOV lanes typically focus on vehicle emissions. There are two analysis approaches are frequently considered to assess the potential impact of HOV lanes on vehicle emissions. A first approach is to assess vehicle emissions with and without an HOV lane. Emissions in grams of carbon monoxide (CO), oxides of nitrogen (NOx), and particulate matter (PM10) are estimated based on passenger miles traveled with and without the HOV lane. A second approach focuses on air quality models used during the planning process for an HOV lane. If specific air quality models were used during the planning process for an HOV project, these models can be re-run with data from the performance monitoring program.

Benefit-Cost Ratio

The benefit-cost ratio is the analysis technique typically used with objectives relating to a cost-effective transportation improvement. The benefit-cost ratio is defined as the present value of all benefits divided by the present value of all costs. Projects with a benefit-cost ratio of greater than 1.0 are usually considered cost-effective. To calculate a benefit-cost ratio, the capital and operating cost of an HOV project is needed, along with a value (in dollars) of the benefits. It may be difficult, in some cases, to determine the capital cost of an HOV project if it was part of larger freeway improvement project or was implemented a number of years ago. As a conservative estimate, only the travel time savings accrued to users of the HOV lane is often used to calculate the benefit-cost ratio for an HOV project. More information on the value of time and the use of the benefit-cost ratio can be obtained from the sources listed in Appendix A.

More sophisticated benefit-cost models have been developed for use in some areas. For example, the Cal-B/C model is the California standard for evaluating transportation projects. The model requires numerous input values. In addition to calculating a benefit-cost ratio, other output measures include the net preset value, economic rate of return, and year of economic feasibility.

CHAPTER SEVEN – CONDUCTING ONGOING HOV PERFORMANCE PROGRAMS

Chapter-at-a-Glance

This chapter discusses developing and conducting HOV performance monitoring programs. It presents information on developing and implementing a data collection program, the frequency of data collection, potential funding sources, and staffing and resource needs. The chapter contains the following sections.

- **Developing and Implementing a Data Collection Program**. This section highlights the basic elements to consider in developing an HOV data collection program. Elements discussed include determining data collection techniques, sites, time periods, and schedules. Staff training, equipment checklists, and pilot test sessions are also described.
- **Frequency of Data Collection and Reporting**. This section highlights the frequency of data collection activities associated with HOV performance monitoring programs. The section describes the frequency of data collection for HOV facilities that have been operating for different periods of time.
- **Potential Funding Sources**. This section highlights potential federal, state, metropolitan, and local funding sources to consider for HOV performance monitoring programs.
- **Staffing and Resources**. This section highlights elements to consider in staffing and resource needs associated with different data collection methods and other elements associated with HOV performance monitoring programs.

Developing and Implementing a Data Collection Program

The use of sound and consistent data collection techniques is critical to ensure the integrity of an HOV performance monitoring program. Elements to consider in developing and implementing a data collection program include reviewing data requirements and existing data sources, and establishing the data collection techniques, the data collection locations, and the data collection time periods. Other elements focus on identifying a data collection schedule, developing data collection assignments and check lists, conducting training for field personnel and staff, performing pilot test sessions, and conducting the actual data collection efforts. Each of these steps is described next.

- **Review Data Requirements**. A first step in developing a data collection program is to review the data requirements associated with the objectives and measures of effectiveness. The data collection program needed to analyze the measures of effectiveness is organized to obtain this information.

- **Establish Data Collection Techniques**. A second step is to match the appropriate data collection techniques to the data requirements. The data collection techniques typically used with HOV performance monitoring programs are discussed in Chapter Five. The data collection techniques used in a specific area will be influenced by a number of factors, including the number and type of HOV lanes, the presence of an advanced transportation management system, existing data collection efforts, and available resources. Building on existing data collection and analysis programs, as well as existing capabilities can help maximize resources.
- **Establish Data Collection Locations**. After the data collection techniques have been identified the next step is to establish the data collection locations. As noted previously, sites for conducting visual vehicle volume, vehicle classification, and vehicle-occupancy counts should provide a clear view of the HOV lane and general-purpose freeway lanes and should provide a safe location for the data collection vehicle and personnel. The sites should also not impact the safety of motorists. Data collection sites should be at the maximum use point along the HOV and freeway facility.
- **Establish Data Collection Time Periods**. The time periods data will be collected must be identified. The HOV lane operating hours will influence the data collection time periods. Typically, data collection activities focus on the time periods when traffic is heaviest and congestion levels are highest. Data is usually collected for the morning and afternoon peak hours and peak-periods. While the exact times for these periods will depend on local conditions, typical peak hours are 6:45 a.m. to 7:45 a.m. and 4:30 p.m. to 5:30 p.m., while typical peak periods are 6:00 a.m. to 9:00 a.m. and 4:00 p.m. to 7:00 p.m. If an HOV lane operates on a 24/7 basis or extended hours, data may also be collected during the off-peak periods. These times might include mid-day and evening hours.
- **Develop Data Collection Schedule**. After the data collection hours have been established, a data collection schedule is developed. This schedule should include the days of the week and the months when data collection activities will be conducted. Historically, data collection activities have been conducted on days that represent normal weekday conditions. As a result, Monday and Friday are often avoided, as travel on these days tends to be different than Tuesday through Thursday. Consideration may be given to including data collection on Monday and Friday with HOV facilities for a number of reasons. First, ignoring these days eliminates 40 percent of the work week. Second, HOV lanes may provide the most significant benefits on these days due to higher volumes in the general-purpose freeway lanes. Third, individuals who may not use the lanes for

their regular commute trips may do so on these days for recreational travel oriented toward long weekends.

The time of year data is collected is also important. Data collection during holiday periods and the summer should be avoided, unless they are conducted as part of a frequent, regularly scheduled data collection effort. The fall and spring represent the best times of the year for routine data collection. In addition, data collection activities should not be conducted during periods of inclement weather which may significantly impact normal traffic conditions. For example, data collection activities should be rescheduled if a major rain or snow storm occurs during the planned time period.

These general rules of thumb would not apply for special data collection efforts focusing on a specific time period, such as the monitoring of weekend use, or if an advanced transportation management system is in place though which data are continuously obtained. When possible, the data collection activities should be conducted on the same days for the HOV facilities and the general-purpose freeway lanes.

- **Data Collection Assignments and Checklists**. For field data collection activities, assignments of personnel to specific sites and time periods must be made. Using a data collection assignment form assists in organizing personnel. A data collection assignment form typically contains a listing of the site location, date, time period, vehicle, and personnel. A data collection checklist should be used to ensure the correct assignment of equipment and materials. Checklists are especially important for equipment-intensive data collection methods, such as floating car travel time runs. Checklists also help ensure that personnel have all the necessary materials for the specific data collection activity.
- **Conduct Training**. As noted in Chapter Five, training of data collection personnel is important to ensure use of the proper techniques and the safety of field staff. Training should include classroom sessions addressing correct data collection techniques and safety procedures. Collecting data in congested travel corridors can be dangerous, so safety should be a primary consideration in training field personnel. Training is also needed for staff responsible for data reduction and analysis.
- **Perform Pilot or Test Activities**. Conducting pilot test sessions for travel time runs, vehicle-occupancy counts, and other field data collection activities is an excellent method to train new personnel and re-train existing staff. Pilot activities allow field personnel to become familiar with data collection procedures, equipment, and locations. Pilot tests also help identify potential problems or the need for additional resources.
- **Conduct Data Collection**. After the above steps are completed, the actual data collection activities are conducted. Personnel overseeing the data collection should monitor the daily assignments, trouble shoot

equipment and staff problems, and supervise the data transfer or reduction activities. Procedures should be established for canceling field data collection due to extreme weather conditions, major crashes, or equipment malfunctions.

Frequency of Data Collection and Reporting

In determining the appropriate frequency of data collection activities, consideration should be given to the type of HOV facility, the operating periods, the data collection methods, the maturity of the HOV lanes, available resources, and changes or anticipated changes in the operating environment. The desired outcome is to best utilize the available resources to ensure a basic ongoing level of data collection to effectively monitor and evaluate the HOV facility.

Data collection activities should be tailored to the type of HOV facility and operating characteristics. For example, short contraflow or concurrent flow lanes that operate only during the peak periods require lower levels of effort than longer exclusive or concurrent flow lanes. Areas with numerous HOV lanes require higher levels of data collection than areas with one or two HOV lanes.

The maturity of the facility may also influence data collection efforts. The frequency of data collection may be reduced over time. If changes have occurred or are anticipated in the operating environment, however, more frequent data collection may be appropriate. Examples of possible changes include increasing or decreasing the minimum-occupancy requirements, changing the hours of operation, and opening other HOV or transit facilities. Anticipating these changes should allow for conducting the appropriate data collection activities to evaluate the impact of these changes.

A base level of data collection, analysis, and reporting matched to common HOV objectives and measures of effectiveness can be identified. For new HOV lanes, before data on vehicle volumes, vehicle classification, vehicle-occupancy, travel time, travel speed, trip time reliability, bus services and ridership, and crashes should be obtained. If possible, before data should be collected more than one time. Establishing a trend line over multiple years is desirable.

Data are typically collected more frequently during the initial operating phase of a new HOV lane or after major changes in operation have occurred. Key data on vehicle volumes and classification, vehicle-occupancy, violations, and crashes may be collected monthly or quarterly during the initial phase of operation. As a facility matures, the data collection schedule typically lengthens, with key data collected quarterly or annually. Surveys of users and non-users may be conducted every two-to-five years. Reporting annually on key performance measures and objectives provides critical information to all stakeholder groups. Chapter Eight contains more information on reporting methods and frequency.

Table 7.1 outlines a suggested desired and minimum level of data collection. In terms of providing information needed to assess typical HOV project objectives and measures of effectiveness, the vehicle and occupancy counts and travel time runs for the HOV lane and freeway general-purpose freeway lanes are the most important.

Thus, limited resources would best be used in obtaining accurate vehicle and occupancy counts and travel time data.

Table 7.1. Suggested Data Collection Frequency.

Data Collected	Facilities	Frequency[1]	
		Desirable	Minimum
Vehicle and Occupancy Counts	HOV facility, freeway, and park-and-ride lots	Quarterly	Annually[2]
Travel Time and Travel Speed	HOV facility and freeway	Quarterly	Annually[2]
Crash Information	HOV facility and freeway	Quarterly	Annually[2]
Violation Rates	HOV facility	Quarterly	Annually[2]
Surveys	HOV facility and freeway	1-2 years	3-5 years

[1] It may be appropriate to focus these activities on the A.M. peak period if initial data collection activities indicate this approach is appropriate.
[2] For HOV facilities that have reached a stable operating condition, it may be appropriate to collect this information every 12 to 18 months.

Potential Funding Sources

Funding for developing and conducting ongoing HOV performance monitoring programs may come from a variety of federal, state, and local sources. Data collection, monitoring, and evaluation activities are eligible project expenses for HOV lanes constructed using federal funds. These activities may also be funded through federal demonstration projects. Monitoring and evaluating early HOV projects was conducted under the federal Service and Methods Demonstration (SMD) program. Assessments of existing HOT projects have been funded through the federal Value Pricing program and data collection and evaluation of bus rapid transit (BRT) projects have been funded through programs conducted by FTA. Other possible federal sources include metropolitan and statewide planning funds, and state planning and research funds. In addition, federal funding supporting the development and operation of advanced transportation management systems and other related systems supports HOV data collection and analysis efforts.

State departments of transportation, MPOs, public transportation agencies, and local governments often provide the local match required on many federal funding programs, as well as providing additional funding for different aspects of HOV performance monitoring programs. Funding for state gasoline sales taxes, state vehicle taxes, local sales taxes, bonding, and other sources may be used.

Staffing and Resources

The staffing and resources needed to conduct the different elements of ongoing HOV performance monitoring programs will depend on a number of factors. These factors include the number, type, and age of HOV lanes in the area, as well as the data collection techniques, frequency of data collection and analysis, and frequency and method of performance reporting. The approach used to conduct different functions will also influence needed staffing and resources. Possible approaches include conducting all functions within one or more agencies, contracting with a university or university-affiliated group, and contracting with one or more consulting firms.

Typically, one individual at the agency operating the HOV lanes will be responsible for overseeing the HOV performance monitoring program. The level of effort and percentage of overall job responsibilities will depend on the scope of the performance monitoring program. Additional staff, either in-house, with other agencies, or with universities or consulting firms, will be needed for data collection, data reduction, data analysis, and report preparation. The skill sets of these groups are very different.

Table 7.2 provides an example of the data collection staffing associated with field data collection activities for one HOV lane corridor in Houston when vehicles counts were taken be field observers and when the floating car technique was used to collect travel time data. Personnel are also needed to transfer the field data into spreadsheets or databases. Staff with computer software skills are needed to manipulate and analyze the data. Staff with more extensive computer capabilities may be needed if data is obtained from advanced transportation management systems. Personnel in an agency's communication group or public information group may assist with developing the appropriate reports, fact sheets, and Internet information.

Table 7.2. Example of Staffing Requirements for Data Collection Activities for the US 290 Corridor in Houston[1].

Data Collection Activity	Staffing Requirement
Vehicle and Occupancy Counts	
Freeway Mainlanes	3[2]
Freeway Frontage Road	1
HOV Lane	2
Parallel Alternate Route	1[3]
Travel Time Runs	
Freeway Mainlanes	4[4]
HOV Lane	4[4]
Surveys	
On-Board Bus	8[5]
Carpool/Vanpool	2[6]
Freeway Mainlanes	1[6]

[1] These staff requirements reflect the collection of vehicle and vehicle-occupancy counts by field personnel and travel time data using the floating car technique.
[2] One person is needed for each freeway mainlane. Thus, on a 4-lane facility, 4 people would be needed.
[3] One person is needed for each parallel route.
[4] A total of 4 people, 2 people per vehicle.
[5] Refers to personnel needed to distribute and collect surveys on the buses. This allows all surveys to be completed on one day.
[6] Refers to personnel needed to read license plates at specific locations on the facility. The staffing requirements depend on the number of recording locations.

CHAPTER EIGHT – HOV PERFORMANCE REPORTING

Chapter-at-a-Glance

This chapter describes approaches for reporting information on HOV system performance to various stakeholder groups. The chapter summarizes how the information is used by different stakeholders in developing policies, funding, planning, designing, operating, managing, and enforcing HOV systems. Reporting methods presented include on-line data, technical reports, fact sheets, brochures, PowerPoint presentations, the Internet, and videos and DVDs. The chapter contains the following sections.

- **Stakeholder Information Needs and Reporting Methods**. This section reviews the use of HOV performance information by various stakeholders and the different methods that may be appropriate for providing the needed information. The frequency of reporting to the different stakeholder groups is also described. A matrix is provided highlighting the reporting methods that may be most appropriate for various stakeholder groups.
- **HOV Performance Reporting Methods**. This section describes the different reporting methods in more detail. Examples are provided of the various approaches used by transportation agencies to report on the performance of HOV facilities.

Stakeholder Information Needs and Reporting Methods

The information generated by HOV performance monitoring programs is of interest and use to numerous stakeholders. These stakeholders include agency staff responsible for operating HOV facilities, agency staff responsible for planning and designing future HOV facilities, federal agency staff and transportation professionals in other areas, agency management personnel, elected and appointed officials, members of the print and electronic media, and the public and special interest groups.

The information presented, the level of detail, and the communication method should be tailored to the needs of the various stakeholder groups. The scope, content, and detail used in different documents and presentations should be appropriate for the audiences being addressed. The information presented should focus on the key performance measures. Maintaining consistency among the different reporting approaches can help save staff and financial resources. For example, the same key information and graphics can be used in reports, fact sheets, brochures, PowerPoint presentations, and the Internet with slight changes. The accompanying text can be expanded or reduced as appropriate. A name, telephone number, e-mail address, and Internet sites should be included in all reporting methods for follow-up questions or comments.

Keys to successful reporting on the results of HOV performance monitoring programs include focusing on the most important measures of effectiveness and tailoring information to the needs of different stakeholders, while maintaining consistency in the reporting formats. The scope, content, and level-of-detail should be appropriate to the various stakeholders. These stakeholders include agency technical staff, federal agency staff and transportation personnel in other areas, agency management personnel, elected and appointed officials, the media, and the public. Possible reporting approaches include on-line data, technical reports, fact sheets, brochures, PowerPoint presentations, the Internet, and videos and DVDs. Contact information, including telephone numbers, e-mail addresses, and Internet sites should be included on all reporting methods.

Information should be presented in a clear, concise, and readable manner that allows individuals to easily identify the purpose of the data and the changes that have occurred. A good performance monitoring program can be wasted if the results are poorly presented. Spending adequate time and resources to ensure clear and well-presented reporting is essential.

The data collection and analysis schedule will influence the frequency of reporting on HOV performance. As noted previously, collecting key data on an annual basis is strongly encouraged. This schedule allows reporting on the major performance measures to also occur annually. More frequent data collection and reporting may be appropriate on new HOV facilities or when significant changes in operations are made. In addition, quarterly data on key operating measures may be provided to agency personnel responsible for operating HOV facilities.

Possible uses of the information generated by HOV performance monitoring programs by different stakeholders and the reporting methods that may be appropriate for each group are described next. Table 8.1 highlights the reporting techniques that may be considered with different stakeholders. Potential communication techniques include on-line data, technical reports and summaries, fact sheets, brochures, PowerPoint presentations, the Internet, and videos and DVDs.

- **Technical Staff Responsible for Operating HOV Facilities**. Technical staff responsible for daily operation, enforcement, and management of HOV facilities typically use real-time, near-term, and historical information. Items of interest include HOV facility use by mode, travel times, trip time reliability, crash statistics, violation rates, transit ridership, and park-and-ride and park-and-pool lot use. This information is needed to make operational decisions that may be required based on changing conditions. Methods to provide this information include quarterly and annual technical reports, fact sheets, and access to on-line data.

Reporting Methods	**Stakeholder Groups**					
	Local Technical Staff	National Technical Staff/ Researchers	Agency Management Personnel	Elected/ Appointed Officials	Media	Public/ Interest Groups
On-Line Data	√	√				
Technical Reports/ Summaries	√	√				
Fact Sheets	√	√	√	√	√	√
Brochures			√	√	√	√
PowerPoint		√	√	√	√	√
Internet	√	√	√	√	√	√
Video/DVD			√	√	√	√

√ **–** primary audiences.

Table 8.1. Stakeholder Groups and Reporting Methods.

- **Technical Staff Responsible For Planning and Designing HOV Facilities**. Technical staff responsible for planning and designing HOV lanes also need detailed information on HOV facility use, travel time, trip time reliability, crashes, violation rates, transit ridership, and park-and-ride and park-and-pool lot use. Quarterly and annual reports are frequently used by this group. These reports should provide a detailed level-of-analysis on the different HOV facilities. Planning and design staff are also interested in the results of special surveys, such as market sheds for park-and-ride lots and surveys of HOV lane users, which can help in planning future facilities.
- **Federal Agency Staff and Transportation Professionals in Other Areas**. HOV performance information may be required or requested by FHWA, FTA, and other federal and state agencies. As noted previously,

SAFETEA-LU includes provisions for performance monitoring requirements if certain exempt vehicles are allowed to use HOV facilities. In addition, transportation staff at agencies, consulting firms, and research groups throughout the country frequently have an interest in HOV performance information. Reporting methods appropriate for these groups include on-line data, technical reports, fact sheets, brochures, PowerPoint presentations, the Internet, and videos and DVDs.

- **Agency Management Personnel**. Information targeted toward agency management personnel should highlight the key performance measures related to HOV facility operations. These individuals are interested in knowing how the facilities are performing related to the objectives and measures of effectiveness, as well as any critical issues that may emerge. Agency management personnel use this information for making recommendations and decisions related to project funding, allocating staff resources, and determining priorities. Agency management personnel have limited time, so information should be displayed graphically and in brief, concise text. Fact sheets, brochures, PowerPoint presentations, and the Internet are appropriate methods of communication with this stakeholder group. Briefing management personnel on a quarterly or semi-annual basis is appropriate, unless more frequent communication is needed to address issues. Videos or DVDs may be appropriate with new management personnel or when major changes have been made in an HOV facility.
- **Elected and Appointed Officials**. Information targeted toward policy makers, commissioners, and elected and appointed officials should also focus on the key performance measures. These stakeholders are responsible for funding decisions, establishing policies, and setting priorities related to transportation investments, including HOV facilities. Similar to agency management personnel, these individuals have very limited time for reviewing detailed reports. Providing graphics and concise text on the key performance measures is a good approach. Fact sheets, brochures, PowerPoint presentations, the Internet, and videos or DVDs may be appropriate communications methods with these stakeholders. Communicating with these individuals on at least an annual basis is a good approach. More detailed briefings are typically used with newly elected and appointed officials.
- **Members of the Print and Electronic Media**. The media provides a link to the public and to policy makers. Ensuring that media personnel have correct information is critical to presenting an accurate picture on HOV facilities. Information targeted toward the print and electronic media should also highlight the key performance measures. Providing graphics that can be used in print or on television can help ensure that the correct information is communicated to their audience. Providing information in "sound bites" is also a good strategy. Communication with the media

should be coordinated through an agency's public information office (PIO) or communications group. Fact sheets, brochures, PowerPoint presentations, the Internet, and videos or DVDs are appropriate for communicating with the print and electronic media. Periodic tours of HOV facilities may also be appropriate, especially with new print or electronic media personnel and when new HOV facilities are opened or major changes in operations occur. Information should be provided to the media on a quarterly or semi-annual basis, with more frequent communication during the opening of an HOV facility or when major changes are made to an existing project.

- **General Public, Including Special Interest Groups**. The information and communication methods used with the media are also appropriate for the general public and special interest groups. Information should focus on the key performance measures, and should be in a format that is clear and concise. Graphics can help communicate critical messages. Information can also be tailored to the specific topics or issues of interest to a group or area. Fact sheets, brochures, PowerPoint presentations, the Internet, and videos and DVDs may be appropriate reporting methods with the public and special interest groups. Providing annual updates on established HOV lanes is typically sufficient. More frequent communication is appropriate on new HOV facilities or when significant changes in operation are made.

HOV Performance Reporting Methods

As noted in the previous section, the typical methods of communicating information on HOV performance to the various stakeholder groups include on-line data, technical reports, fact sheets, brochures, PowerPoint presentations, the Internet, and videos and DVDs. Each of these approaches is described in more detail in this section and case study examples are provided as appropriate.

On-Line Data

Data from ITS and other advanced technology monitoring systems may be available in real-time for agency staff responsible for operating and managing HOV facilities. Real-time data is typically available to personnel located in transportation management centers, as well as other locations. This information may be used to make daily operating decisions, such as opening an HOV lane to all traffic in the case of a major incident on the freeway lanes, as well as monitoring trends over time for possible changes in operation.

Technical Reports

Technical reports provide relatively detailed information on all of the measures of effectiveness. Technical reports provide historical information, trend lines, and current operating data. Historical information should include the opening dates of various HOV elements and major milestones in operations. Trend line information highlights use levels and other performance measures over time. The most recent data are presented to provide a current snapshot on operation of the HOV facility.

Technical reports typically contain summary tables, charts, and graphs. Photographs and maps may also be used to highlight specific elements. The text provides a description of each measure of effectiveness. Technical documents form the basis for other reporting methods. Key information from these reports can be highlighted in fact sheets, brochures, PowerPoint presentations, and the Internet.

Technical reports should be prepared based on the data collection schedule. Annual reports, containing updates of the major performance measures, are recommended. Figures 8.1, 8.2, and 8.3 provide examples of the information provided in the quarterly reports on the Houston HOV facilities. Figure 8.4 illustrates one of the graphics in the Houston quarterly reports.

Houston and Dallas Technical Reports

Annual technical reports were prepared on the Houston HOV lanes from the mid-1980s to the late 1990s as part of an ongoing TxDOT-sponsored research project. These reports provide detailed information on the performance of the HOV lanes, park-and-ride and park-and-pool lots, and other elements of the HOV system. Information on the HOV lanes in Dallas was incorporated into the reports early in the 1990s. Houston METRO and DART also sponsored data collection efforts over the years. Quarterly summary reports continue to be prepared.

Minnesota Department of Transportation – Quarterly HOV Reports

The Minnesota Department of Transportation (Mn/DOT) publishes quarterly reports documenting key information on the I-394 and I-35W HOV lanes in the Minneapolis area. The reports include tables and graphs highlighting vehicle and person volumes, occupancy levels, and persons per lane, for both the HOV lanes and the general-purpose lanes. The quarterly report for the I-394 HOV lane also tracks use of the ABC parking garages in downtown Minneapolis that provide discount rates for carpoolers.

California Department of Transportation, District 7 HOV Annual Report Evaluation Summary

The California Department of Transportation (Caltrans) District 7 publishes an *HOV Annual Report Executive Summary***.** The report presents general information on the HOV lanes in District 7, which includes Los Angeles and Ventura Counties. Changes during the year are highlighted, along with an overall operating summary. Fact sheets are included for each HOV lane, documenting the characteristics and operation of the lane and presenting graphs comparing vehicle and person volumes in the HOV and general-purpose lanes.

Figure 8.1. Houston HOV Lane Operational Summary.

MEASURE	KATY HOV LANE		NORTH HOV LANE		GULF HOV LANE		NORTHWEST HOV		SOUTHWEST HOV		EASTEX HOV LANE		TOTAL HOV LANES	
	Vehicles	Persons	Vehicles	Persons	Vehicles	Persons	Vehicles	Persons	Vehicles	Persons	Vehicles	Persons	Vehicles	Persons
A.M. PEAK HOUR														
Buses	35	1,560	57	2,665	30	1,400	22	1,170	46	1,775	17	810	207	9,380
Vanpools	19	133	17	118	15	105	16	125	6	45	5	19	78	545
Carpools	1,078	2,409	1,373	2,766	1,306	2,578	1,127	2,324	1,164	2,498	414	844	6,462	13,419
Motorcycles	38	38	36	36	18	18	27	27	5	5	14	14	138	138
Total	1,170	4,140	1,483	5,585	1,369	4,101	1,192	3,646	1,221	4,323	450	1,687	6,885	23,482
A.M. PEAK PERIOD														
Buses	83	3,525	124	5,335	74	2,805	51	2,540	110	3,755	39	1,740	481	19,700
Vanpools	45	311	46	302	28	217	40	293	21	148	23	139	203	1,410
Carpools	3,223	7,153	3,120	6,320	2,561	5,032	3,293	6,726	2,400	5,111	897	1,810	15,494	32,152
Motorcycles	97	97	64	64	40	40	67	67	25	25	31	31	324	324
Total	3,448	11,086	3,354	12,021	2,703	8,094	3,451	9,626	2,556	9,039	990	3,720	16,502	53,586
P.M. PEAK HOUR														
Buses	40	1,860	62	2,575	28	1,185	25	1,120	41	1,735	15	710	211	9,185
Vanpools	28	206	17	132	15	99	17	109	7	53	11	70	95	669
Carpools	1,104	2,427	1,185	2,397	1,112	2,289	1,442	2,976	832	1,777	449	928	6,124	12,794
Motorcycles	35	35	24	24	7	7	36	36	2	2	39	39	143	143
Total	1,207	4,528	1,288	5,128	1,162	3,580	1,520	4,241	882	3,567	514	1,747	6,573	22,791
P.M. PEAK PERIOD														
Buses	101	4,295	128	5,105	67	2,485	57	2,305	100	4,005	39	1,615	492	19,810
Vanpools	49	337	58	392	33	210	44	301	34	268	29	190	247	1,698
Carpools	3,367	7,544	2,946	5,993	2,339	4,818	3,391	7,047	1,910	4,082	883	1,838	14,836	31,322
Motorcycles	98	98	69	69	25	25	101	101	13	13	47	47	353	353
Total	3,615	12,274	3,201	11,559	2,464	7,538	3,593	9,754	2,057	8,368	998	3,690	15,928	53,183
TOTAL DAILY														
Buses	184	7,820	252	10,440	141	5,290	108	4,845	210	7,760	78	3,355	973	39,510
Vanpools	94	648	104	694	61	427	84	594	55	416	52	329	450	3,108
Carpools	9,362	20,241	7,118	14,417	5,433	10,916	7,404	15,213	4,998	10,569	1,995	4,078	36,310	75,434
Motorcycles	195	195	133	133	65	65	168	168	38	38	78	78	677	677
Total	9,835	28,904	7,607	25,684	5,700	16,698	7,764	20,820	5,301	18,783	2,203	7,840	38,410	118,729

Note: Daily system totals for non-METRO buses are 101 buses and 3,470 persons.

Figure 8.2. Houston HOV Lane Comparison.

FACILITY	MEASURE	JUNE 2004	MARCH 2005	JUNE 2005	YEARLY PERCENT CHANGE	QUARTERLY PERCENT CHANGE
IH 10W KATY FREEWAY HOV LANE						
A.M. Peak Period	TOTAL VEHICLES	3,373	3,393	3,448	2.22	1.62
	TOTAL PERSONS	11,586	9,969	11,086	-4.32	11.20
	TOTAL CARPOOLS	3,131	3,213	3,223	2.94	0.31
	TOTAL CARPOOLERS	6,827	6,651	7,153	4.78	7.55
P.M. Peak Period	TOTAL VEHICLES	3,641	3,553	3,615	-0.71	1.75
	TOTAL PERSONS	11,799	11,419	12,274	4.03	7.49
	TOTAL CARPOOLS	3,407	3,355	3,367	-1.17	0.36
	TOTAL CARPOOLERS	7,390	7,102	7,544	2.08	6.22
IH 45N NORTH FREEWAY HOV LANE						
A.M. Peak Period	TOTAL VEHICLES	3,215	3,443	3,354	4.32	-2.58
	TOTAL PERSONS	13,023	12,618	12,021	-7.69	-4.73
	TOTAL CARPOOLS	2,951	3,257	3,120	5.73	-4.21
	TOTAL CARPOOLERS	5,933	6,463	6,320	6.52	-2.21
P.M. Peak Period	TOTAL VEHICLES	3,209	3,264	3,201	-0.25	-1.93
	TOTAL PERSONS	12,408	12,631	11,559	-6.84	-8.49
	TOTAL CARPOOLS	3,018	3,007	2,946	-2.39	-2.03
	TOTAL CARPOOLERS	6,383	6,235	5,993	-6.11	-3.88
IH 45S GULF FREEWAY HOV LANE						
A.M. Peak Period	TOTAL VEHICLES	2,636	2,629	2,703	2.54	2.81
	TOTAL PERSONS	8,487	7,685	8,094	-4.63	5.32
	TOTAL CARPOOLS	2,505	2,530	2,561	2.24	1.23
	TOTAL CARPOOLERS	5,162	5,093	5,032	-2.52	-1.20
P.M. Peak Period	TOTAL VEHICLES	2,251	2,396	2,464	9.46	2.84
	TOTAL PERSONS	7,607	7,267	7,538	-0.91	3.73
	TOTAL CARPOOLS	2,142	2,262	2,339	9.20	3.40
	TOTAL CARPOOLERS	4,617	4,858	4,818	4.35	-0.82
US 290 NORTHWEST FREEWAY HOV LANE						
A.M. Peak Period	TOTAL VEHICLES	3,107	3,365	3,451	11.07	2.56
	TOTAL PERSONS	8,611	9,172	9,626	11.79	4.95
	TOTAL CARPOOLS	2,969	3,226	3,293	10.91	2.08
	TOTAL CARPOOLERS	5,968	6,465	6,726	12.70	4.04
P.M. Peak Period	TOTAL VEHICLES	3,246	3,168	3,593	10.69	13.42
	TOTAL PERSONS	9,391	8,784	9,754	3.87	11.04
	TOTAL CARPOOLS	3,076	3,045	3,391	10.24	11.36
	TOTAL CARPOOLERS	6,761	6,126	7,047	4.23	15.03
US 59S SOUTHWEST FREEWAY HOV LANE						
A.M. Peak Period	TOTAL VEHICLES	2,589	2,520	2,556	-1.27	1.43
	TOTAL PERSONS	9,134	9,187	9,039	-1.04	-1.61
	TOTAL CARPOOLS	2,439	2,364	2,400	-1.60	1.52
	TOTAL CARPOOLERS	5,078	4,890	5,111	0.65	4.52
P.M. Peak Period	TOTAL VEHICLES	2,455	2,112	2,057	-16.21	-2.60
	TOTAL PERSONS	8,789	7,881	8,368	-4.79	6.18
	TOTAL CARPOOLS	2,302	1,971	1,910	-17.03	-3.09
	TOTAL CARPOOLERS	4,803	4,094	4,082	-15.01	-0.29
US 59N EASTEX FREEWAY HOV LANE						
A.M. Peak Period	TOTAL VEHICLES	853	867	990	16.06	14.19
	TOTAL PERSONS	3,728	3,370	3,720	-0.21	10.39
	TOTAL CARPOOLS	750	798	897	19.60	12.41
	TOTAL CARPOOLERS	1,558	1,593	1,810	16.17	13.62
P.M. Peak Period	TOTAL VEHICLES	816	847	998	22.30	17.83
	TOTAL PERSONS	3,478	3,603	3,690	6.10	2.41
	TOTAL CARPOOLS	718	787	883	22.98	12.20
	TOTAL CARPOOLERS	1,460	1,679	1,838	25.89	9.47

Figure 8.3. Park-and-Ride/Park-and-Pool Lot Utilization Pre-HOV Lane and HOV Lane Comparison.

CORRIDOR	FACILITY	LOT CAPACITY (Spaces)	PRE-HOV LANE		CURRENT SAMPLE	
			Parked Vehicles	Percent of Capacity	Parked Vehicles	Percent of Capacity
KATY FREEWAY (IH 10W)						
	Kingsland P-N-R	2,247	217	9.7	1,627	72.4
	Mason Road P-N-P	386	+	+	64	16.6
	Fry Road P-N-P	374	+	+	43	11.5
	Barker-Cypress P-N-P	409	+	+	29	7.1
	Addicks P-N-R	2,428	358	14.7	1,840	75.8
NORTH FREEWAY (IH 45N)						
	Woodlands P-N-R	990	+	+	424	42.8
	Spring P-N-R	1,263	+	+	831	65.8
	Kuykendahl P-N-R	2,171	+	+	1,422	65.5
	Seton Lake P-N-R	1,286	+	+	620	48.2
	North Shepherd P-N-R	1,603	+	+	342	21.3
GULF FREEWAY (IH 45S)						
	Bay Area P-N-R	1,155	516	44.7	624	54.0
	Bay Area P-N-P	208	+	+	314	151.0
	Fuqua P-N-R	938	+	+	813	86.7
	South Point P-N-R	376	+	+	363	96.5
	Monroe P-N-R	904	+	+	268	29.6
NORTHWEST FREEWAY (US 290)						
	Northwest Station P-N-R	2,361	401	17.0	2,346	99.4
	Little York P-N-R	1,102	44	4.0	465	42.2
	Pinemont P-N-R	938	+	+	197	21.0
	Northwest TC P-N-R	195	+	+	143	73.3
SOUTHWEST FREEWAY (US 59S)						
	Missouri City P-N-R	779	283	36.3	134	17.2
	West Bellfort P-N-R	1,416	+	+	1,206	85.2
	Mission Bend P-N-R	862	72	8.4	59	6.8
	Westwood P-N-R	826	464	56.2	635	76.9
	Gessner P-N-R	415	+	+	108	26.0
	Hillcroft TC P-N-R	922	+	+	326	35.4
	West Loop P-N-R	772	358	46.4	274	35.5
EASTEX FREEWAY (US 59N)						
	Kingwood P-N-R	1,034	780	75.4	624	60.3
	Townsen P-N-R	996	+	+	508	51.0
	Eastex P-N-R	877	297	33.9	270	30.8
	Tidwell TC P-N-R	809	27	3.3	10	1.2

+ Facilities not in operation prior to HOV treatment.

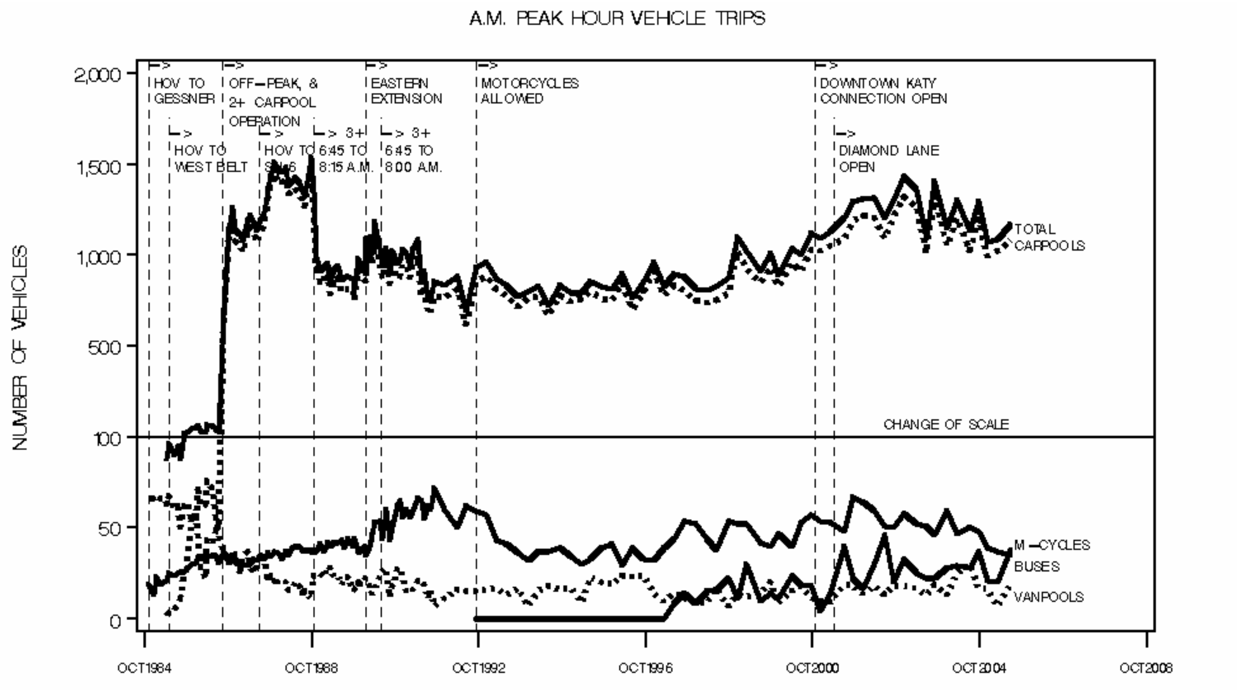


Figure 8.4. Houston I-10 West HOV Lane AM Peak Hour Vehicle Trip Summary.

Fact Sheets

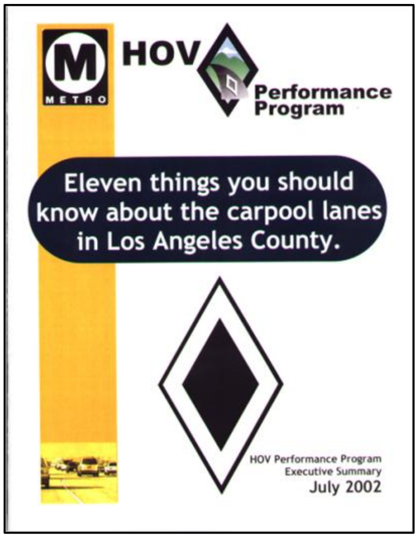
Fact sheets can be used to present key HOV performance measures to all stakeholder groups. Information from a technical report is typically summarized or reformatted for the fact sheets. Fact sheets can also be tailored to different audiences. For example, fact sheets highlighting HOV lane bus ridership trends may be used with public transportation agency policy boards, while fact sheets summarizing enforcement and violation rates may be targeted toward enforcement personnel.

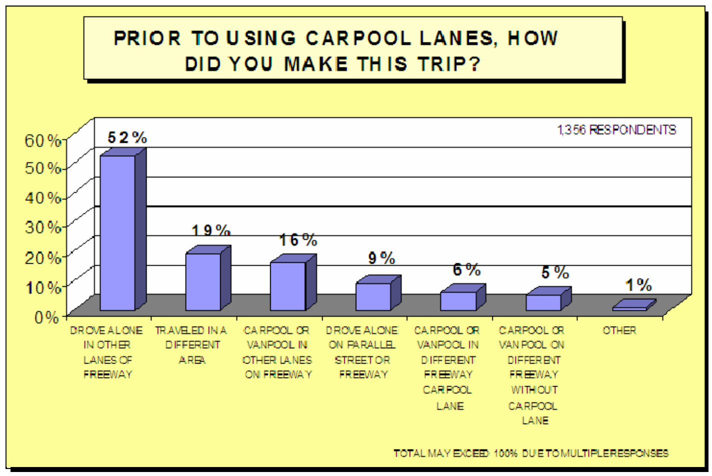
Brochures

Brochures can also be used to present the results of HOV performance monitoring programs. Brochures may be appropriate to communicate information on the performance of new HOV facilities, the results of major evaluation efforts, and ongoing monitoring activities. Brochures are typically targeted toward agency management personnel, policy makers, the media, and the public. The *Eleven Things You Should Know About the Carpool Lanes in Los Angeles County* brochure presents the results of a major evaluation effort, while the *HOV Facility System in Houston* and the *ABC's of HOVs* brochures highlight the results of ongoing monitoring efforts of HOV facilities in Houston and Dallas.

Eleven Things You Should Know About the Carpool Lanes in Los Angeles County

The executive summary of the HOV Performance Monitoring Program sponsored by the Los Angeles County Metropolitan Transportation Authority (MTA) in the early 2000s highlighted 11 key findings from the assessment. The brochure uses photographs, charts, and graphs, along with brief text, to present the major findings. The document has been used to communicate with the MTA board, policy makers in the area, the media, and the public.





HOV Facility System in Houston and The ABCs of HOVs

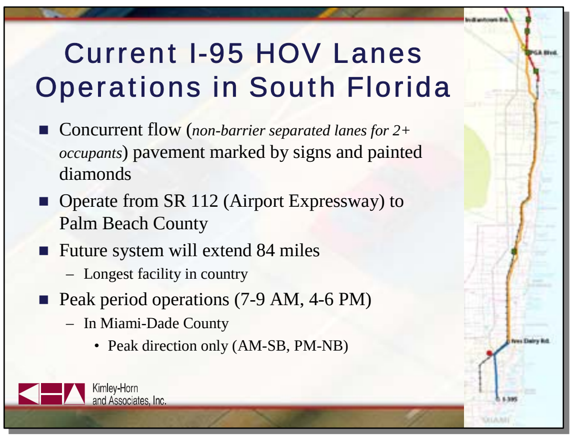
A brochure, *The HOV Facility System in Houston*, was published in 1991. The brochure highlights the results of the ongoing monitoring program sponsored by Houston METRO and TxDOT. Photographs, charts, and graphs are used to present key information. *The ABCs of HOV's*, published in 1999 as part of a TxDOT-sponsored research project, highlights the use of HOV lanes in Houston and Dallas. The document summarizes the experience with HOV facilities in the two metropolitan areas. Graphics are used to present key performance information.

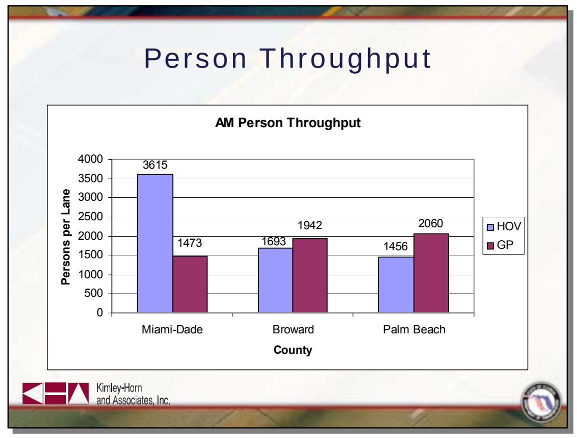
PowerPoint Presentations

Information from technical reports and other reporting methods can also be used in PowerPoint presentations. Graphics are especially effective in PowerPoint. PowerPoint is frequently used in presenting information on HOV performance at professional conferences and in meetings with agency management personnel, policy boards, and public interest groups. PowerPoint presentations are typically updated as new information is available from ongoing data collection and analysis activities.

I-95 HOV Lanes in South Florida

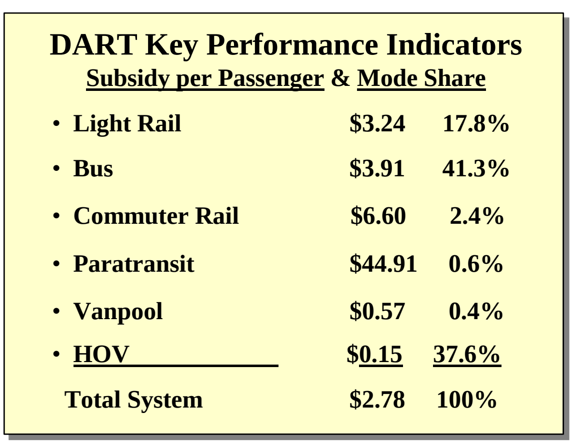
A PowerPoint presentation was developed as one method for presenting the results of the I-95 HOV system-wide operations study sponsored by the Florida Department of Transportation (FDOT) District Four and Six. The PowerPoint slides highlight the purpose of the study, activities conducted, the major findings, and the strategies for HOV system improvements. The PowerPoint presentation has been used with numerous local technical and policy groups, as well as at national conferences.

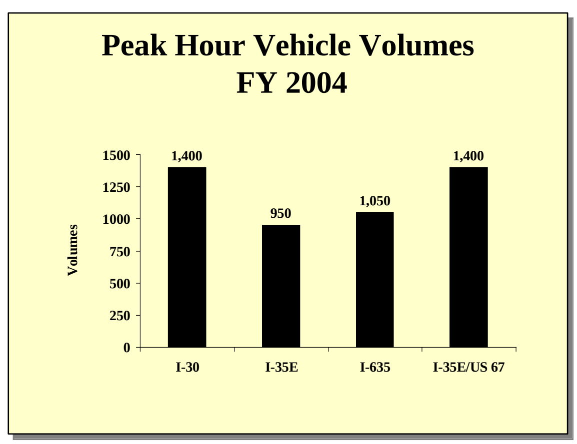




Dallas HOV Facilities

PowerPoint presentations are used by Dallas Area Rapid Transit (DART) to highlight the ongoing role HOV facilities play in the Dallas area. Photographs, maps, graphs, and charts are used to illustrate key points. The PowerPoint slides are used in presentations to policy boards, local groups, and at national conferences.





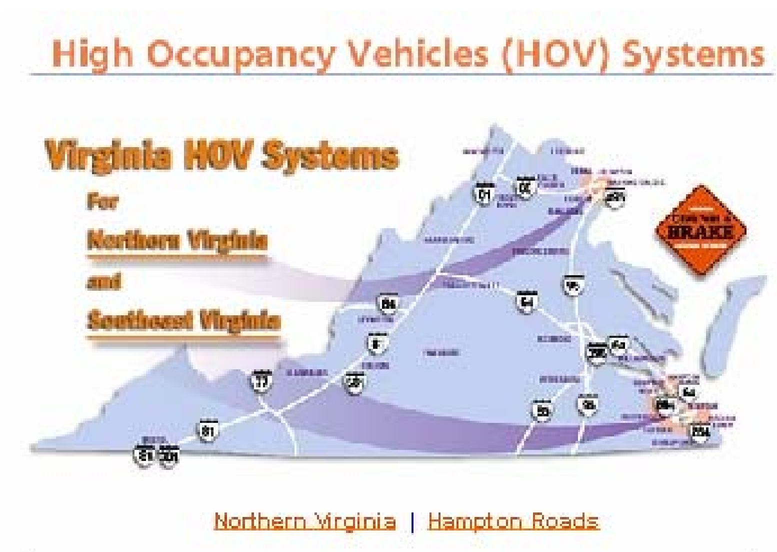
Internet

Posting information from HOV performance monitoring programs on an agency's Internet site is a good way to reach many stakeholder groups. HOV performance information may be provided as part of an agency's overall performance measures or in a special section on HOV facilities.

The graphics and narrative developed for brochures, fact sheets, PowerPoint presentations, and other reporting methods may be adapted for use on the Internet. Similar to other reporting formats, information on the Internet should focus on the key performance measures and should be clearly explained. Graphics can be used to illustrate key points. In addition, more detailed reports on HOV monitoring and evaluation programs, survey results, and other activities can be posted on an agency's Internet site.

Virginia Department of Transportation Internet Site

The Virginia Department of Transportation's (VDOT) Internet site includes a section devoted to HOV facilities in the state. The Internet site includes information on using the HOV lanes, recent reports relating to the HOV lanes, frequently asked questions, and future plans. The site also includes "virtual drives" of the HOV lanes. The recent reports by the HOV Enforcement Task Force are provided on the site. Contact information is provided for directing questions and comments about the HOV facilities.



Washington State Department of Transportation and Washington State Transportation Center Internet Sites

The Washington Department of Transportation's (WSDOT) Internet sites includes a section devoted to HOV facilities in the Puget Sound Region. The site includes information on use of the lanes, the status of HOV projects, and reports on use levels and evaluations. In addition, the Washington State Transportation Center (TRAC) maintains Internet sites that contain data on the HOV lanes. These sites are still in the development stage, but they allow users to analyze available data for different HOV segments.

Videos and DVDs

Videos and DVDs may also be used to present information on the performance of HOV facilities. These methods have not been used extensively due primarily to the cost and time involved. Videos were prepared on HOV facilities in a few areas during the 1980s and 1990s. The focus of these videos was primarily on introducing the HOV concept and new HOV lanes, rather than on extensive performance monitoring activities. FHWA and other agencies also sponsored the development of a video on HOV facilities throughout the country for national distribution in the 1980s.

CHAPTER NINE – CASE STUDIES

Chapter-at-a-Glance

This chapter presents examples of HOV performance monitoring programs in use throughout the country. The case studies highlight approaches and techniques described in previous chapters. The case studies demonstrate the use of different objectives, measures of effectiveness, data collection techniques, analysis methodologies, and reporting approaches. They provide a mix of project types, institutional arrangements, and scope. The following case studies are presented in the chapter.

- **Houston HOV Facilities**. This section highlights the key elements of the initial before-and-after assessment of the I-45 North contraflow lane demonstration program and the ongoing monitoring efforts, including monitoring the QuickRide HOT project on two HOV lanes.
- **HOV Lanes in Northern Virginia and Maryland**. This case study summarizes the initial before-and-after assessment of the Shirley Highway (I-395) Bus-on-Freeway demonstration project. The ongoing monitoring of HOV lanes in northern Virginia and Maryland is also described, including monitoring exempt low-emission and energy-efficient vehicles with clean special fuel license plates in northern Virginia.
- **HOV Facilities in the Puget Sound Region**. This case study describes the ongoing performance monitoring program of HOV lanes in the Puget Sound Region. The evolution of data collection procedures and analysis techniques is highlighted.
- **Los Angeles HOV Lanes**. This case study highlights the initial assessment of the El Monte Busway on the San Bernardino Freeway, the ongoing monitoring by Caltrans, and the Los Angeles MTA HOV performance monitoring program.
- **I-394 HOV Lane in Minneapolis**. This case study examines the data collection and evaluation program conducted on the interim and final HOV lanes on I-394. The ongoing performance monitoring program is also summarized. Monitoring and evaluation of the MnPASS HOT project is described.
- **I-15 HOV Lanes in San Diego**. This case study presents information on the monitoring activities associated with the different phases of the HOT project on the I-15 HOV lanes in San Diego.

Houston HOV Facilities

This case study describes the evaluation conducted on the I-45 North contraflow lane demonstration project and the ongoing monitoring of the Houston HOV lane system. The data collection and analysis efforts associated with the QuickRide HOT projects on two HOV lanes are summarized. The case study highlights the changes in data collection procedures that have occurred to take advantage of advanced technologies. The HOV monitoring efforts represent the joint efforts of TxDOT and METRO. TTI has been responsible for the data collection and analysis activities.

The first HOV facility in Houston was the I-45 North contraflow lane demonstration project, implemented in 1979. The success of this project led to the development of additional HOV facilities in other freeway corridors. Currently, approximately 104 miles of HOV lanes are in operation in six freeway corridors in Houston. The HOV lanes are primarily one-lane, barrier separated facilities located in the freeway median.

The evaluation procedures, measures of effectiveness, and data collection activities associated with evaluating the effectiveness of the Houston HOV lanes have evolved over the years to take advantage of changes in technology. A brief review of the process used with the initial evaluation of the I-45 North Freeway contraflow lane demonstration project and the development of the current procedures is provided first, followed by the ongoing data collection activities.

The I-45 North Freeway contraflow lane was implemented as a federally-funded demonstration program. As such, a fairly extensive before-and-after evaluation was conducted on the project. The evaluation was conducted by Cambridge Systematics, Inc. TTI assisted with many of the data collection activities. The project objectives and evaluation measures as outlined in the final report are highlighted below.

Project Objectives

- Decrease (or slow the growth of) corridor vehicle miles of travel (VMT) and associated fuel consumption and vehicle emissions.
- Increase vehicle occupancy in the corridor.
- Reduce congestion and thus, decrease travel time.
- Encourage acceptance and usage of public transportation.

Evaluation Measures

- Person and vehicle utilization.
- Characteristics of both contraflow lane users and non-priority travelers.
- Impact on non-priority users of the freeway.
- Influence in promoting bus and vanpool use.
- Associated safety and enforcement issues.
- Public acceptance.
- Impacts on corridor VMT, fuel consumption and vehicle emissions.
- Associated costs.

As other HOV lanes were planned and implemented in Houston, a standardized evaluation program and corresponding monitoring and data collection program began to emerge. TxDOT and METRO have sponsored this effort, although the exact level of funding by each agency has varied. The major elements of this process focused on data collection efforts needed to evaluate the following objectives.

- Increase the effective person-movement capacity of the freeway.
- HOV lane implementation should not unduly impact the general-purpose freeway lane operation.
- The HOV lane project should be cost effective.
- Development of the HOV lanes desirably will have public support.
- HOV lanes should have favorable impacts on air quality and energy consumption.

To evaluate the HOV lanes based on these general objectives, data has been collected and analyzed by TTI on a regular basis. Over the years, the procedures have evolved to take advantage of new technologies and improved processes. The following list provides a summary of the major elements of the ongoing monitoring and data collection program.

- **Vehicle and Occupancy Counts**. Vehicle and occupancy counts are taken on the HOV lanes and the general-purpose freeway lanes. Initially, counts were also conducted on two freeways that did not have HOV lanes to act as a control group. In addition, vehicle and occupancy counts were conducted on eight arterial streets that served as alternative routes to the HOV lanes and freeway facilities and on freeway frontage roads. Currently counts are conducted on a quarterly basis on the HOV lanes and the general-purpose freeway lanes. Both vehicle and occupancy counts were initially conducted by field personnel. The count locations and examples of the count forms are provided in Chapter Five. Tube counters are now used to obtain vehicle counts, while vehicle-occupancy counts are still conducted by field personnel.

- **Park-and-Ride Lot Counts**. The number of vehicles parked at the park-and-ride and park-and-pool lots associated with the HOV lanes is counted quarterly. Initially, these counts were conducted on a monthly basis, and counts were also conducted at lots along the two control freeway corridors.

- **Travel Time Data**. Travel time runs were initially conducted on the HOV lanes and adjacent general-purpose freeway lanes using the floating car technique. Travel time runs were also made on the control freeways. The data collection method changed after the implementation of TranStar, the advanced transportation management center for the Houston area, and the automated vehicle identification (AVI) system. The speed data from the AVI system is used to estimate travel times for the HOV lanes and the general-purpose freeway lanes. The results are compared and the travel time savings provided to users of the HOV lanes are calculated.

- **User and Non-User Surveys**. Surveys of bus users, carpoolers, and vanpoolers using the HOV lanes and single occupant vehicles in the general-purpose freeway lanes were conducted on a regular basis during the 1980s and 1990s. These surveys were designed to obtain information on user's and non-user's perception of HOV lane utilization, reasons for mode choice selection, and general attitudes toward the HOV lanes. Surveys were also conducted as part of the QuickRide project. As described in Chapter Five, license plates of vehicles in the HOV and general-purpose freeway lanes are recorded and sent to the Motor Vehicle Division, which provides a list of addresses for the registered vehicle owners. The surveys are mailed to addresses in the Houston area. On-board ridership surveys are distributed to individuals as they board buses at park-and-ride lots and collected by field personnel riding the buses. Special surveys have also been distributed to casual carpoolers at selected locations.

- **Crash Data**. The METRO transit police are responsible for responding to crashes in the HOV lanes. METRO police are also responsible for documenting the crashes and maintaining the crash records. The METRO crash data table includes the date, time, and location of each crash. It also includes the damage rating, comments by the reporting police officer, the driver's age range, and the type of ticket issued. The damage rating classifies crash damage as major or minor, indicates the number and types of vehicles involved, and notes if fixed objectives were hit. The comment section provides a brief description of how the crash occurred. Information from the METRO police records is included in the quarterly reports. For each corridor the number of crashes is listed. The crash rate, which is the number of crashes per 100,000 vehicle trips, is also calculated and provided in the quarterly reports.
- **Violation Rates**. METRO Transit Police are responsible for enforcing vehicle-occupancy levels and other operating requirements. METRO provides a summary of the violation rates on the HOV lanes. The vehicle and occupancy counts also provide a check on violation rates, which are summarized in the quarterly reports.

A number of methods have been used to report the results of the monitoring activities. These methods include detailed reports, monthly summary reports brochures, and PowerPoint presentations. These reporting techniques are highlighted below.

- **Technical Reports**. Annual reports were prepared on the HOV monitoring and evaluation program during the late 1980 and 1990s as part of a TxDOT-sponsored research project. These reports described the current status of the HOV system and provided longitudinal information on all the HOV lanes and park-and-ride and park-and-pool lots. The reports presented the results of user and non-user surveys. Assessments of major changes, such as the increase in vehicle-occupancy levels on the I-10 West HOV lane for 2+ to 3+ during the peak hours, were included as appropriate. Separate reports were also prepared documenting the detailed results of the user and non-user surveys.

- **Quarterly Summary Reports**. Quarterly reports are prepared documenting the vehicle classification, vehicle-occupancy counts, the speed and travel time data, and the counts at park-and-ride and park-and-pool lots. Tables, charts, and graphs are used to present the information for each HOV corridor. Examples of these reporting methods are provided in Chapter Eight.
- **Brochures.** A brochure, *The HOV Facility System in Houston*, was published in 1991. The brochure highlights the results of the ongoing monitoring program sponsored by Houston METRO and TxDOT. Photographs, charts, and graphs are used to present key information. *The ABCs of HOV's*, published in 1999 as part of a TxDOT-sponsored research project, highlights the use of HOV lanes in Houston and Dallas. The document summarizes the experience with HOV facilities in the two metropolitan areas. Graphics are used to present key performance information.
- **PowerPoint Presentations.** Information from the HOV monitoring program is used by METRO, TxDOT, and TTI personnel in PowerPoint presentations. These presentations are used at meetings and conferences at the local, state, and national level.

The QuickRide program, which was implemented in January 1998 on I-10 West, allows registered two-person carpools to use the HOV lane for a $2.00 per trip fee during the 3+ occupancy requirement periods – 6:45 a.m. to 8:00 a.m. and 5:00 p.m. to 6:00 p.m. The program was expanded to include the US 290 HOV lanes during the morning peak hour in 2000. Individuals are required to register for the program and must have an active electronic tag account. The electronic tags are read by the AVI system.

A variety of data collection activities were conducted to monitor the QuickRide program. Data on the number of users was obtained through the AVI system. Mail surveys were conducted of QuickRide participants, and an on-board ridership survey of bus passengers was conducted. Casual carpoolers were surveyed by distributing mail back surveys to individuals waiting for rides at three park-and-ride lots.

HOV Lanes in Northern Virginia and Maryland

The Shirley Highway (I-395) HOV lanes were one of the first major HOV facilities in North America. An initial five-mile, bus-only lane was opened in 1969. Additional segments of the facility were opened in 1970 and 1971, with the 11-mile, two-lane reversible, barrier-separated HOV facility completed in 1975. Only buses were allowed to use the facility during the initial stages, with vanpools and carpools added later.

A number of evaluation studies have been conducted on the Shirley Highway HOV lanes. The first of these was completed on the initial Express-Bus-on-Freeway Demonstration project from 1971 to 1975. The demonstration and evaluation were jointly sponsored by the Urban Mass Transportation Administration (UMTA) and FHWA. It was conducted by the Technical Analysis Division, National Bureau of Standards, U.S. Department of Commerce. A total of five reports were prepared documenting different aspects and time periods of the demonstration.

The initial demonstration project, which at the time was the largest bus and highway project ever sponsored by the Department of Transportation, had three major components. These were the 11 miles of HOV lanes, the use of new-feature buses in express service, and the development of new park-and-ride lots coordinated with the express bus service. The final report lists the following primary and secondary goals of the project, related objectives, and the evaluation measures.

Primary Goal: Demonstration that express bus-on-freeway operations can improve the quality of bus service and lead to an increase in the people-moving capability of peak period transportation facilities for the entire urban corridor.

Objectives:

- Increase reliability of bus service.
- Reduce travel time for transit and automobile commuters.
- Increase coverage by bus routes.
- Increase bus passenger convenience and comfort.
- Increase bus' share of corridor commuters.

Measures:

- Operating speeds.
- Door-to-door travel times.
- Reliability of service.
- Coverage area of bus service.
- Passenger comfort and convenience features (seat availability, fewer transfers, etc.).
- Increase in bus patronage and market share.
- Increase in carpooling and reduction in single-occupant automobiles.
- Growth in person volumes (bus and automobile) per lane on the Shirley Highway and the resulting changes in the quality of service encountered by both bus and automobile commuters.

Secondary Goal: Demonstration that technology can produce a favorable impact on the transportation-related environmental and social conditions within a corridor and on the economic condition of the transit operator.

Objectives:

- Reduce peak period automobile pollutant emissions.
- Reduce peak period gasoline consumption.
- Increase mobility of the transportation disadvantaged.

- Increase productivity of the bus operator.

Measures: To determine changes on the social and economic objectives, the following changes were measured:

- Economic Impact – operating costs and capital expenditures, and savings from increased productivity for bus operators.
- Environmental Impact – gasoline consumption and automobile pollutant emissions.
- Social Impact – use of bus service by transit dependent households.

Specific thresholds or performance standards were not set for each of the objectives or measures upon which the project's success would be evaluated. Rather, general terms, such as "improve," "increase," and "reduce" were used to describe the desired results.

Extensive data collection and analysis activities were conducted as part of the demonstration evaluation program. These included traffic counts, surveys, and the use of analytical procedures to estimate some impacts. A summary of the major data collection and analysis efforts follows.

- **Vehicle Volumes and Person Trip Counts**. Periodic counts were made of peak-period vehicular volumes and person trips (bus and automobile) crossing an eight-station screen line that intersected the main radial arterials in the corridor. This information was used to determine the overall changes in travel within the corridor, and specifically on the Shirley Highway. It was used to analyze changes in total person trips, bus person trips, bus market-share, and automobile-occupancy rates.
- **Monitoring Bus Schedule Adherence**. Surveys of bus schedule adherence, as measures by a comparison of the actual arrival time of buses at the first downtown stop with the time listed in the printed schedule, were conducted prior to the opening of the entire busway and seven times throughout the demonstration.
- **Monthly Bus Data**. The bus operator provided monthly information on passenger levels, aggregate system costs, revenues, and operating statistics. These were used to evaluate the impact on the transit operator.
- **Bus and Automobile Travel Times**. These elements were measured directly by travel time and speed surveys, and indirectly through asking peoples' perceptions in the mail-out and passenger surveys.
- **General and Specific Commuter Surveys**. A number of surveys were used to identify changes in commuter behavior, the reasons for these changes and general perceptions. In-depth, mail-back surveys of automobile and bus commuters in the corridor were conducted in the initial state and final stage of the demonstration. Surveys of park-and-ride lots users and bus riders were conducted.

- **Analytical Procedures**. Specific analytical procedures were developed to estimate bus market share, commuter travel time savings due to the HOV lanes, bus operating costs, and reductions in automobile volumes, gasoline consumptions, and air pollutant emissions.

The final report suggested two additional elements for consideration in future evaluations. First, while the evaluation process for the Shirley Highway Express-Bus-on-Freeway did include surveys of users of the HOV lanes and single-occupant drivers in the corridor, it did not include any corridor-wide household surveys. This was noted as one weakness of the evaluation in the final report, and it was suggested that this type of survey be included in future evaluations. In addition, the report recommended the development of a better procedure for identifying and analyzing reductions in bus vehicle and driver requirements attributable to the higher speeds on the HOV facility.

Since the initial demonstration program evaluation, which was completed in 1975, there have been a number of other studies that have examined different operational aspects of the Shirley Highway HOV lanes. In the mid-1990s the Metropolitan Washington Council of Governments (WASHCOG), initiated an ongoing monitoring, evaluation, and reporting program on HOV lanes in northern Virginia. In addition to I-95/I-395, the other HOV lanes in northern Virginia include I-66 and the Dulles Toll Road. In Maryland, the HOV lanes on I-270 and the I-270 Spur and US 50 (John Hanson Highway) are included in the monitoring program.

The data collection procedures used by WASHCOG are described next. Data collection occurs on Tuesdays, Wednesdays, and Thursdays. Data collection is scheduled to avoid holiday periods, and is deferred if severe weather is forecasted.

- **Vehicle Classification and Occupancy Counts**. Vehicle classification and occupancy counts are conducted by field personnel at selected locations along each corridor. Field personnel are trained by WASHCOG staff in the procedures to classify vehicles and to count the number of occupants. One individual is assigned to each HOV and general-purpose freeway lane. A laptop computer with a BASIC denominator program is used to record each vehicle and the number of observed occupants. The data are recorded on disk and processed in the office.

  WASHCOG uses a special methodology to estimate vanpool occupancy levels to address two problems. The first problem was that many vans have tinted windows making it hard for field personnel to count occupants. Second, the traffic counting software highest occupancy count was seven. Vanpools are defined as vans with eight or more occupants. Field personnel use the “v” button to record vanpools. Field personnel are trained to recognize the larger 15-passenger vans and the smaller eight-passenger minivans. The number of occupants in a minivan is counted if possible. For the larger vans, a vanpool occupancy factor of 12 passengers is used based on the results of a mail survey of vanpool operators.

  In the fall of 2003, WASHCOG started counting exempt low-emission and energy-efficient vehicles with clean special fuel license plates on the HOV lanes in northern Virginia. Additional field personnel record the number of vehicles with the clean special fuel license plates at each of the count stations.

- **Travel Times**. Travel time data are collected using the floating car technique. The travel time runs are conducted in tandem with one vehicle using the HOV lane and one vehicle using the general-purpose freeway lanes. Travel time runs are performed in the peak direction of travel. Both vehicles begin at the same location at the same time. Travel time runs in the morning begin between 6:45 a.m. and 7:50 a.m. In the afternoon, travel time runs begin between 4:45 p.m. and 5:20 p.m. The results of the travel time runs are calculated and averaged for the HOV lanes and the general-purpose freeway lanes. The time savings provided by using the HOV lanes are calculated and presented.
- **Transit Patronage Data**. Ridership data on bus and rail services in the different corridors is obtained from the public transportation agencies and private operators. Agencies providing service in the different corridors include the Washington Metropolitan Transportation Authority (WMATA), Fairfax County, City of Alexandria, Virginia Rail Express (VRE), Potomac and Pappahannock Transportation Commission (PRTC), Loudon County, and the Maryland Mass Transit Association (MTA). The ridership data is presented for buses using the HOV lanes and the general-purpose freeway lanes, as well as Metrorail and commuter rail. A load factor was developed for other buses, such as charters, inner-city, and school buses using the HOV lane, and is applied to those categories of buses recorded in the vehicle classification counts.

The vehicle classification and occupancy data is presented in tables by 30-minute increments. The average automobile occupancy is calculated for each count station. The average automobile occupancy is also used to calculate the number of automobiles needed to carry 1,000 persons. These two figures – the average automobile occupancy and the number of automobiles needed to carry 1,000 people based on that occupancy rate – are presented for the HOV lanes and the general-purpose freeway lanes in each corridor. Table 9.1 provides an example of how this information is presented. The person movement is also calculated for the HOV lanes and general-purpose freeway lanes.

WASHCOG publishes annual reports on the HOV monitoring program. Key data on average automobile occupancy and travel time savings are presented and described. Trend lines are discussed and changes from the previous year are noted. The count data is provided in 30-minute increments for each location in an appendix.

Table 9.1. Observed Average Automobile Occupancies in the A.M. Peak Direction during HOV-Restricted Periods (Fall 1997).

FACILITY	HOV Lane Average Automobile Occupancies[1]	Number Of Automobiles Needed To Move 1,000 Persons At HOV Occupancy Rate	Non-HOV Lane Automobile Occupancies	Number Of Automobiles Needed To Move 1,000 Persons At Non-HOV Occupancy Rate
I-395 (Shirley Highway – North of Virginia 120)	2.70	370	1.13	885
I-95 (Shirley Highway – North of Newington)	2.65	377	1.11	901
I-66 (Exclusive HOV Facility, East of I-495)	1.84[2]	543	N/A[3]	N/A
I-66 (Concurrent Flow HOV Facility, West of I-495)	2.03	492	1.07	935
I-270 (East Leg)	1.90	526	1.05	952
I-270 Spur (West Leg)	1.91	524	1.07	935

1 Average automobile occupancies include vanpool vans and motorcycles, which are permitted on all HOV facilities in the Washington region.
2 Average automobile occupancies on the I-66 HOV facility include single-occupant vehicle (SOV) traffic coming from Dulles Airport.
3 There are no conventional (non-HOV) lanes along this section of I-66.

HOV Lanes in the Puget Sound Region

The Puget Sound HOV case study highlights a number of elements. First, techniques for monitoring and evaluating HOV lanes in the Puget Sound region have evolved over the years. Second, the monitoring, analysis, and reporting process represents the coordinated efforts of the Washington State Department of Transportation (WSDOT), the Washington State Transportation Center (TRAC), transit agencies, and other groups. Third, many of the data collection techniques have progressed from manual methods to the use of electronic sensors and other advanced technologies as part of the FLOW system. Finally, the presentation of information from the monitoring program has also evolved from printed reports to extensive use of the Internet, including providing access to different databases.

In 1983, six miles of concurrent flow HOV lanes were opened on I-5 in Seattle. Evaluations of the facility were conducted at three months and 20 months. The following six general measures of effectiveness were used in the evaluation to determine the impact of the HOV lanes.

- The number of vehicles traveling in the lanes.
- The number of people served by the lanes.
- The extent to which people are obeying the laws governing the HOV lanes.
- The time savings for freeway commuters.
- The affect on the accident rate.
- Public reaction.

Data collection activities for the evaluations included vehicle and occupancy counts for the HOV lane the second week of operation, at three months, and at 20 months. The average daily traffic (ADT) for the general-purpose freeway lanes was also examined for the same time periods. Violation studies were conducted during the second and third month of operation, and after the implementation of the regional peer violation reporting telephone hotline (764-HERO) in early 1984. Travel time savings were measured as part of the annual metropolitan travel time study. Public reaction was measured by the number of letters and telephone calls to WSDOT on the HOV lanes.

The *Washington State Freeway HOV System Policy*, published in 1991, outlines 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 versus outside) and separation, general-purpose freeway lane conversion, HOV system performance, promotion, design standards, land use coordination, and supporting programs, services, and facilities. It represents one of the more comprehensive set of HOV policies currently in use by a state department of transportation. The policies were developed by a multi-agency stakeholder group and adopted by senior management and the Transportation Commission.

The FLOW system is a coordinated network of traffic monitoring, measuring, information dissemination, and control devices operated on the Interstate and urban state highways in the region. Monitoring and measuring elements include closed-circuit television (CCTV) and electronic sensors. Information dissemination techniques include variable message signs (VMS), highway advisory radio (HAR), and the WSDOT Internet site. Control devices include HOV lanes and meters at selected freeway entrance ramps.

The HOV lane monitoring program focuses on four main elements. These elements are vehicle volumes in the HOV and general-purpose freeway lanes, vehicle-occupancy levels, bus ridership, and travel times in the HOV lanes and general-purpose freeway lanes. Enforcement levels and violation rates, and user and non-user attitudes are also monitored. Procedures for acquiring vehicle volume data from the FLOW system, performing analyses, and presenting outputs have been developed and documented by TRAC. These procedures and tools include the programs noted next. In addition, analysis procedures for calculating AVO, speed, and travel time have been developed and documented.

- Compact Disc Data Retrieval (CDR) – This program retrieves and reformats raw traffic data for each lane type and direction from one specific cabinet and one loop at a time for use by CDR Analyst.
- CDR Auto – This program retrieves and reformats raw traffic data from multiple cabinets by lane type and direction for use by CDR Analyst.
- CDR Analyst and Associated Utilities – This program computes performance measures and presents the analyzed data in text and graphical formats.

Vehicle-occupancy data is collected by visual inspection at 15 routine data collection sites. These sites cover all corridors with HOV lanes. The sites are selected for good sight lines into passing vehicles and for safety of staff performing the counts. Data are collected in the morning and afternoon peak periods six times a year when it is light enough to observe the number of occupants in a vehicle. Data for the HOV and general-purpose freeway lanes are counted separately for the morning peak period and the afternoon peak period. A more limited number of mid-day counts are conducted at fewer locations.

Bus ridership information is obtained from the four transit authorities in the region. Ridership on specific routes at specific locations is requested. The transit authorities may use automated passenger counters or other methods to collect this information.

Public opinion surveys are conducted on a periodic basis. Mail out/mail back surveys have been used with HOV users and motorists in the general-purpose freeway lanes. Surveys of transit riders are conducted by distributing questionnaires to passengers on buses and providing a pre-paid, return envelope.

The following primary measures are used to assess the performance of HOV lanes in the Puget Sound Region.

- **Vehicle Volume**. The number of vehicles recorded at a specific freeway and HOV lane location during the weekday morning and evening peak commute periods, as well as during an average 24-hour weekday. Vehicles per lane per hour (vplph) and other measures are calculated.
- **Person Volume**. The number of passengers measured at a specific freeway and HOV lane location during the weekday morning and evening peak commuter periods. Person throughput is computed by combining vehicle volume and vehicle-occupancy data.
- **Average Vehicle Occupancy**. The average number of occupants in a vehicle, including persons in cars, vanpools, and transit buses at a given

HOV lane and freeway location during weekday morning and evening peak commute periods.

- **Speed and Trip Reliability**. The average vehicle speed based on the average travel time for a given trip. The trip reliability measure is the percentage of time that the vehicle travels less than 45 mph.
- **Travel Time**. The average time in hours and minutes required to complete a trip from point A to point B based on trip start time, throughout an average weekday.

The following secondary measures are used to assess the HOV lane performance.

- **HOV Violations**. Indicators used to assess HOV violations include violations observed on area highways by traffic observers, tickets and warning issues by law enforcement officers, and activity levels on the region peer violation reporting hotline (764-HERO).
- **Public Opinion**. Surveys are conducted on a regular basis to obtain public opinion data on the HOV program's perceived importance and effectiveness.

A variety of methods have been used to present the results from the ongoing HOV monitoring program. As noted below, these methods include technical reports, summary reports and brochures, and Internet sites.

- **Technical Reports**. For many years technical reports were published annually documenting the performance of the HOV lanes, including the results of user and non-user surveys. Recently, this annual information has been posted on the Internet and the development and publication of lengthy reports has been discontinued.
- **Summary Reports and Brochures**. Summary reports and brochures have also been used over the years to present key findings from the HOV performance monitoring program. These documents use graphics to highlight different performance measures. Figure 9.1 provides an example of graphics from a 2001 report.
- **Internet Sites**. Information on the HOV lanes is available on the WSDOT Internet site. Internet-based publishing of key statistics is being used more. For example, in lieu of publishing formal paper reports on HOV lane performance, TRAC has created a specific Internet site designed to provide access to summary statistics that describe historical HOV lane and general-purpose freeway lane performance. In addition, through a second TRAC Internet site (TRACMAP) access to the underlying HOV and freeway performance statistics is available to researchers and agency staff that need to compare statistics other than those routinely reported.

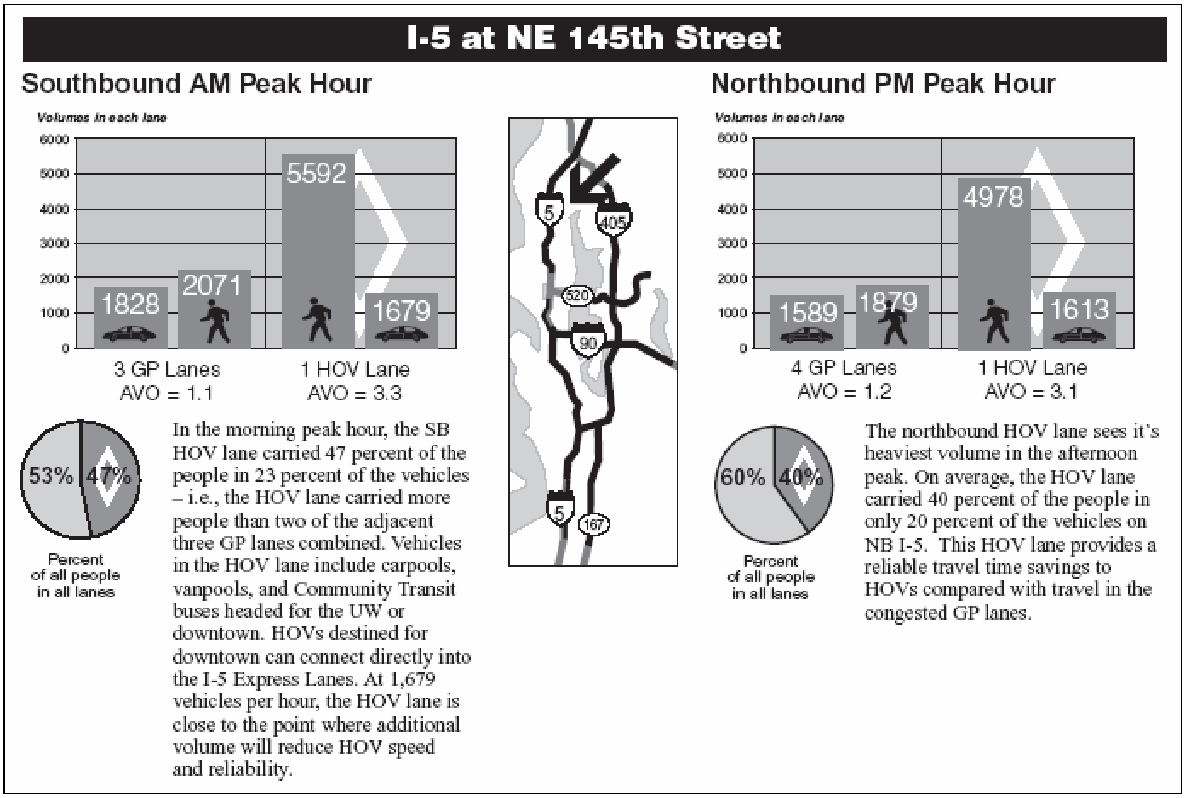


Figure 9.1. Example of Graphic from 2001 Annual Report.

Los Angeles HOV Lanes

The 11-mile San Bernardino Freeway Busway was opened in 1973. The two-lane, two-direction facility was initially restricted to buses only. Carpools and vanpools were allowed to use the facility starting in1976. An initial evaluation of the busway was conducted over the first three years of operation, from 1973 to 1976. An additional analysis of the mixed-mode operation was completed in 1978. The evaluations were conducted as a joint effort of the Southern California Association of Governments (SCAG), Urban Mass Transportation Administration (UMTA), Caltrans, Southern California Rapid Transit District (SCRTD), and the City of Los Angeles. The evaluations were conducted by Crane & Associates.

According the final report of the mixed-mode analysis, a series of goals and measures of effectiveness were identified for the cost-effective analysis. Table 9.2 shows these goals and measures of effectiveness. The relative importance of these different goals was identified by the busway evaluation committee and the corresponding value was used in the analysis. However, the effectiveness measures did not include the use of specific threshold levels. Rather, general terms such as "improve" and "reduce" were used in the evaluation.

Table 9.2. San Bernardino Freeway Busway Evaluation Goals and Effectiveness Measures.

GOAL	EFFECTIVENESS MEASURES	RELATIVE IMPORTANT
Provide added corridor capacity	Increased carrying capacity of the corridor, in persons per peak hour or period.	20%
Reduce environmental impacts of corridor travel	Reduced emissions of air pollutants, in tons per year.	10%
	Energy savings, in BTU-equivalent gallons of gasoline	10%
Improve the level of service.	Travel time savings, in minutes per person trip, and the value of such savings in dollars.	20%
Reduce the cost of personal travel.	User cost savings, in cents per person trip (including parking cost savings).	20%
Improve the safety of corridor travel.	Number of accidents avoided, and the associated dollar savings to society.	15%
Provide for future contingencies (e.g., a rail line, future growth, etc.)	Adaptability of the busway for such situations, plus their likelihood and timing.	5%

The following elements were included in the data collection and analysis process.

- **Travel Time Studies**. Caltrans conducted before-and-after time and speed runs on the busway, freeway, and on several major parallel roadways.
- **Vehicle Volume and Occupancy Counts**. Caltrans also conducted before-and-after vehicle and occupancy counts. This included counts at four locations along the San Bernardino Freeway and one location on the Santa Ana Freeway. Mechanical volume counts were conducted at several locations along the busway, at ramps along the Santa Ana Freeway, and on five parallel surface streets. Occupancy counts were conducted at one location on the freeway and at two locations on the busway.
- **Violation Rates**. Caltrans monitored the number of violators over the five-year period from the occupancy counts and the California Highway Patrol (CHP) provided records of enforcement activities.
- **Bus Ridership and Travel Times**. SCRTD provided weekly ridership counts.
- **Safety**. The CHP collected accident data for the busway.

- **User and Non-User Surveys**. A variety of surveys were conducted to evaluate user and non-user perceptions of the facility and specific reasons for mode selection and mode shift. These surveys included an on-board survey of bus riders, a mail-back survey of carpoolers and a follow-up telephone survey with selected carpoolers, a mail-back survey of general-purpose freeway users, and interviews with bus drivers.

The results of the El Monte Busway monitoring and evaluation program were presented in annual reports for the first three years and a summary report was prepared. Caltrans conducted vehicle volume and vehicle-occupancy counts on a regular basis during the 1980s and 1990s.

The Los Angeles County Metropolitan Transportation Authority (LAMTA) initiated an HOV performance program study in 2000. The project built on the previous HOV evaluation efforts in southern California and the ongoing monitoring activities conducted by Caltrans. The study was conducted to develop a comprehensive monitoring and evaluation program for the HOV system in the county. The program established a framework for the regular review, evaluation, and reporting on the performance of HOV lanes in the county.

The five objectives of the HOV performance program were to:

- enhance existing HOV data collection;
- analyze the travel impacts and user benefits of the HOV system;
- provide policy makers with needed information to make informed decisions concerning the future of HOV lanes in the county;
- sustain, market, and promote user and non-user acceptance of the HOV system; and
- develop policy recommendations to help guide future HOV investments and operations.

The scope of the study included 16 HOV lane segments in 13 of the 14 freeway corridors with HOV lanes. The study also examined five future HOV segments on four freeways. Finally, two freeways not programmed for future HOV lanes were included as control corridors. A total of 23 freeway segments were included in the project.

The project represented the coordinated efforts of agencies in Los Angeles. The MTA was the lead agency, with support and involvement from Caltrans District 7 and Caltrans Headquarters. A Project Advisory Committee (PAC) helped guide the study. The PAC included representatives from the following agencies and groups, in addition to MTA and Caltrans.

- SCAG;
- South Coast Air Quality Management District (SCAQM);
- FHWA and FTA;
- City of Los Angeles;
- City of Long Beach;
- Orange County Transportation Authority (OCTA);

- Foothill Transit;
- Automobile Club of Southern California;
- CHP; and
- University of California, Berkeley.

The first step in the study was to develop a performance monitoring and evaluation plan, including the objectives to guide the performance of the HOV facilities. The performance monitoring and evaluation plan was developed based on a review of existing agency HOV goals and objectives, previous assessments of HOV facilities in the county, national experience, and a workshop with PAC members and other agency staff. The PAC developed the following five objectives. These five objectives are not listed in any priority order.

- Manage travel demand by increasing the person movement capacity in congested freeway corridors.
- Encourage carpooling, vanpooling, and bus use by providing travel and mobility options.
- Provide travel time savings and trip time reliability to travelers using the HOV facilities.
- Provide air quality benefits.
- Promote a cost-effective transportation system.

Measures of effectiveness were identified for each the five objectives. A data collection and analysis program was outlined and conducted to provide the information needed to assess the measures of effectiveness. A data management program was also developed to consolidate HOV-related data collected and maintained by various agencies. The purpose of the HOV performance program data management program (DMP) is to provide an effective tool to organize, store, query, and retrieve available data, and to provide a tool for ongoing monitoring. The DMP, which was developed using available software, provides electronic storage of travel time data, vehicle counts, vehicle-occupancy counts, crash statistics, and transit service and ridership data. Users can analyze data using customized queries, forms, and reports, as well as use GIS to map data.

That data needed for the performance program was obtained from existing sources, and additional data collection activities were conducted. The following data collection and analysis techniques were used to assess the different measures of effectiveness.

- **Vehicle Volumes and Vehicle-Occupancy Data**. Vehicle volume information was obtained from the Caltrans District 7 Traffic Monitoring Group (TAG) loop data. Loop stations at or close to the locations used to obtain the vehicle-occupancy counts were identified. The loop data was obtained for the HOV lane and the general-purpose freeway lanes separately when available, and in both directions of travel. The TAG includes data from 1990 through 2000. For each year, data for the last full week in January, April, July, and October were used in the analysis.

Vehicle-occupancy counts were conducted manually by Caltrans District 7 staff. Bus ridership was obtained from transit operators in the county. The vehicle and vehicle-occupancy data was used to analyze a number of the measures of effectiveness. The AVO, person-trips, and vehicles per hour per lane (vphpl) for the different HOV lanes and general-purpose freeway lanes were calculated and compared.

- **Travel Time and Speed Data**. Caltrans District 7 staff performed travel time runs – called tachometer (tach) runs because the travel time and delay data are recorded automatically from the vehicle tachometer – in the HOV lanes and the general-purpose freeway lanes. The Caltrans Moving Vehicle Run Analysis Package (MVRAP) was used to extract the data and transfer it into a spreadsheet format for analysis. The travel time savings provided by the HOV lanes were calculated. One of the effectiveness thresholds was that travel time saved in the HOV lane should be at least 0.5 minutes per mile for the peak period in the peak direction, compared to the adjacent general-purpose freeway lanes. There were ten of the HOV segments that met or exceeded this threshold.
- **Focus Groups**. As part of the market research element of the performance program, three focus groups were conducted. One focus group was composed of carpoolers who use the HOV lanes, three or more times per week, one focus group was composed of carpoolers who used the HOV lanes not more than twice a week, and one focus group was composed of employer transportation coordinators (ETCs). The carpoolers were recruited randomly by telephone based on carpool list provided by ETCs. The ETCs were recruited from a list of regional ETCs provided by SCAQ. The focus groups were facilitated by a member of the consulting team. The focus groups provided information on the perceptions, attitudes, and ideas about the HOV lanes.
- **Executive Interviews**. A total of 13 interviews were conducted with key elected officials, private sector transportation providers, and transit agency representatives. The interviews, which were conducted by a member of the consulting team, obtained additional information on perceptions about the HOV lanes in the county from these key individuals.
- **HOV Lane Users and Motorists in the General-Purpose Lanes**. A mail out/mail back survey was distributed to the owners of vehicles observed using the HOV lanes, the general-purpose freeway lanes, and freeways without HOV lanes. License plates were recorded on video during the peak period on the different facilities. The video was scanned using specially designed software and the transcribed license plate numbers were sent to the California Department of Motor Vehicles (DMV). Surveys in both English and Spanish were mailed to individuals on the list provide by the DMV. Surveys were also sent to vanpool drivers based on a list obtained from SCAG. Out of a total of 31,751 surveys mailed, 6,178 were returned. An additional 168 surveys were collected from vanpool users.

The survey results indicated strong support for the HOV lanes among users and non-users. The findings also indicated that approximately half of the carpoolers in the HOV lanes previously drove alone and that saving time was the major reason for using the HOV lanes.

- **General Public Telephone Survey**. A telephone survey was conducted to obtain the perspective of the general public toward the HOV lanes. A total of 3,273 surveys were completed. The sample was drawn from nine county subregions in proportion with the population of those subregions. Respondents had to be at least 18 years of age. The survey results indicated strong support for the HOV lanes across all geographic areas. Information on other perceptions related to the HOV lanes, the benefits of the lanes, use of the lanes, and issues associated with their use was also obtained.
- **On-Board Bus Passenger Survey**. An on-board survey was conducted of passengers on buses operating in the HOV lanes. Passengers on five routes were included in the survey. Field personnel distributed the surveys, which were provided in English and Spanish, to passengers as they boarded buses at selected locations and collected the completed surveys. A total of 1,110 completed surveys were received and analyzed. The surveys provided information on trip purpose, reasons for using the bus, prior mode, and socio-economic characteristics of bus riders. Approximately 35 percent of the respondents indicated they previously drove alone.
- **Crash Data and Analysis**. Data from the Caltrans District 7 Traffic Accident Surveillance and Analysis System (TASAS) was used in the performance monitoring program. The analysis examined four tables or sections of the TASAS database. These sections included the cumulative number of crashes by postmarker, selected crash rate calculations, high crash concentration locations, and selected crash retrieval. The selective crash rate calculation data for 1990 through 2000 were examined for all routes. The data are available only for the total freeway – HOV and general-purpose freeway lanes; data are not available separately for the HOV lane and general-purpose freeway lanes.

  As noted above, the TASAS database does not allow for determining the types of accidents by lane. This information can only be obtained from the original accident report on file. The resources in the project were not available for the level of effort required to examine the original accident reports. As a result, the assessment focused on the accident rate for each HOV facility segment and a comparison was made with the statewide average for similar facilities and with the average for the control routes. For each HOV segment, the TASAS data was obtained for two years prior to the lane opening, one-year after opening, and in 1999. The results of this assessment were presented in tables and graphs. No distinct trends or patterns were identified that could be directly attributed to the presence of an HOV lane. In general, freeways in Los Angeles County were at or below the statewide average crash rate for similar types of facilities. The crash rates reflected those of heavily congested freeways in urban areas. The analysis did identify four high crash clusters; one on a freeway segment without an HOV lane, two on which the HOV lane did not appear to be a contributing factor, and one on which weaving into and out of an HOV lane may have been a contributing factor.

- **Benefit-Cost Assessment**. The economic viability of the existing HOV lanes were examined using a modified version of the Cal-B/C Model, which is the standard for evaluating transportation projects in California. The Cal-B/C Model uses data from the "before" or "without project condition," along with projections for future travel demand and information on a proposed project to assess the economic efficiency of the proposed project. The model was modified for the performance project application to include a "with HOV lane" case and to estimate the differences between the "with" and "without" HOV lane scenarios. The model requires a number of input variables related to construction and maintenance costs, as well as average daily traffic, number of lanes, AVO, and other data specific to each HOV lane and freeway. The model outputs include the benefit-cost ratio, the net present value, the economic rate of return, and the year of economic feasibility. The results of this analysis indicated that the HOV lanes in the county were good investments. The average benefit-cost ratio for the 14 HOV segments analyzed was 10.0 and the median was 7.4

A variety of methods were used to present the results of the activities conducted as part of the performance monitoring program. First, periodic newsletters were developed and distributed to members of the PAC, agency personnel, and policy makers. Second, technical memoranda were prepared on the various tasks. Third, a detailed final report was developed, which the presented data collection and analysis methods, and the analysis of the measures of effectiveness. An executive summary, *Eleven Things You Should Know about Carpool Lanes in Los Angeles County*, was prepared and widely distributed to agency management personnel, policy makers, and other groups. PowerPoint presentations have also been given at national conferences highlighting the performance program.

I-394 HOV Lane, Minneapolis, Minnesota

The I-394 case study provides an example of an extensive before-and-after evaluation, an ongoing monitoring program, and a HOT project assessment. Data collection for the initial evaluation began before the opening of the interim HOV lane in 1985.

I-394 represents the last segment of the Interstate system constructed in the Minneapolis-St. Paul metropolitan area. It was built on the alignment of the existing State Highway 12. An interim HOV lane, called the *Sane Lane*, was developed and operated in the Highway 12/I-394 corridor from 1984 to 1993, during construction of I-394. The interim facility included three miles of a reversible, barrier-separated HOV lane located in the median of the highway and additional segments of concurrent flow HOV lanes. The *Sane Lane* was implemented to both help manage traffic during construction of I-394 and to introduce the HOV concept to travelers in the corridor.

The final design of I-394, which opened in1993, includes three miles of two-lane, reversible, barrier-separated HOV lanes and eight miles of concurrent flow HOV lanes. The reversible segment provides a direct connection into parking garages on the edge of downtown Minneapolis, which offer discounted parking fees to carpools. The garages contain a bus transfer station and connections to the skyway pedestrian system.

An extensive before-and-after study of the interim and the final HOV lanes was initiated prior to the opening of the interim facility. The evaluation was funded by FHWA and Mn/DOT, and was conducted by the consulting firm, SRF Inc. A set of project goals and objectives was identified by the I-394 Project Management Team for both the interim and completed facilities. These objectives formed the basis of the evaluation program, which was completed prior to the opening of the interim facility in 1985.

There were three different time periods identified for the project evaluation. These were the construction period, when the interim facility would be in operation, the start-up period for the completed facility, and the stable operating period. The following eight objectives were identified for the HOV facility. Although the objectives were intended to apply to all three evaluation periods, it was noted that the degree to which they might be achieved would vary.

Increase the peak-hour carpool/vanpool model split for the I-394 corridor.

Increase the peak-hour transit modal split for the I-394 corridor.

Improve the level-of-service for mixed traffic on I-394.

Maintain or improve the existing level-of-service for mixed traffic on I-394.

Maintain or improve the accident rate along I-394.

Achieve and maintain a low violation rate of the HOV lanes on I-394.

Construct a cost-effective HOV facility on I-394.

For each of these objectives, specific performance measures were identified and a corresponding performance threshold was established for each time period. The thresholds were established based on an analysis of the existing conditions and the forecast use for the different time periods. Table 9.3 shows the performance measures and the thresholds identified for the objective related to increasing the peak-hour mode split. This information provides an example of the approach and level of detail involved in the I-394 before-and-after evaluation.

The I-394 evaluation program was supported by an ongoing data collection effort. The program included regular vehicle and occupancy counts on the HOV lane, mainlanes, and parallel facilities, travel time runs, accident data, violation rates, surveys of users and non-users, and evaluation of the different marketing and public information programs.

Table 9.3. Example of the I-394 Evaluation Objective and Performance Measures.

Objective	Performance Measure	Existing Conditions 1984	Construction Period 1985-1990	Start-Up Period 1991-1992	Stable Operation 1993-2000
Increase the Auto Peak Hour Modal Split	Carpools/Vanpools	625	700	1,075	1,585
	Carpool/Vanpool/ Occupants	1,380	1,540	2,515	4,900
	Carpools as % of Automobiles	19%	21%	25%	29%
	Carpool Occupants as % of Automobile Occupants	34%	36%	42%	56%
	Automobile Occupant Rate	1.23	1.25	1.3	1.6

Mn/DOT collects and analyzes key data for the I-394 HOV lanes and the concurrent flow HOV lanes on I-35W on a quarterly basis. Information on the number of vehicles moved in the HOV lane, the general-purpose freeway lanes, and the total facility is presented. The percentage of total person movement, the average automobile occupancy rate, and the average bus occupancy rate are also provided. Historical data for the previous four quarters is presented to highlight trend lines and changes in use levels.

The vehicle volumes for the HOV lane and the general-purpose freeway lanes are obtained from loop detector data. The vehicle classification is estimated based on percentages from previous studies, which are conducted periodically to update the classification rates used. Information on the number of transit buses and ridership levels are obtained from public transportation providers in the area.

The MnPASS HOT project was implemented in May 2005. Dynamic pricing is used on the project, with tolls based on the level of congestion. The base toll is $0.25 and the maximum toll is $8.00. The project represents the first use of tolling in the Minneapolis-St. Paul metropolitan area and in Minnesota.

The MnPASS project has a number of objectives. The first objective is to improve the efficiency of I-394 by increasing the person-carrying and vehicle-carrying capabilities of the HOV lanes. The second objective is to maintain freeflow speeds for transit and carpools in the HOV lanes. The third objective is to improve highway and transit in the corridor with the revenues generated from the project. The fourth objective is to deploy electronic toll collection, including tags, transponders, and readers to maintain travel speeds. The final objective is to employ new ITS technologies to facilitate dynamic pricing and in-vehicle electronic enforcement.

A comprehensive evaluation is being conducted on the MnPASS project. The evaluation includes two separate, but coordinated elements; an assessment of the system performance and an assessment of user and non-user attitudes. The system performance component focuses on assessing the impact of the project on the operation of I-394. Speed, travel time, trip time reliability, system throughput, safety, enforcement, and roadway operations are being examined. The reliability and efficiency of the MnPASS toll components are also being evaluated. The attitudinal component is monitoring changes in travel behavior and attitudes associated with the MnPASS project.

I-15 HOV Lanes in San Diego California

The I-15 two-lane barrier-separated HOV facility on the northeast side of San Diego opened in 1988. The eight-mile long facility uses a 2+ vehicle-occupancy requirement. Initially, the lanes were opened in the southbound direction from 6:00 a.m. to 9:00 a.m. and in the northbound direction from 3:00 p.m. to 6:30 p.m.

In 1996, approximately 1,800 vehicles were using the HOV lanes during the morning peak-hour, and the lanes were operating at a level-of-service C. During the same period, the adjacent four general-purpose freeway lanes were carrying 12,000 vehicles, operating at a level-of-service F.

Interest in considering pricing on the HOV lanes emerged during the examination of potential transportation control measures in the regional air quality plan. The pricing approach was supported by the mayor of a suburban community in the corridor. This individual was elected to the State Assembly and sponsored the enabling legislation needed for the project.

An initial demonstration project, funded primarily through the federal value pricing program, was conducted to test the concept of allowing single-occupant vehicles to use the I-15 HOV lanes for a fee. The objectives of the initial demonstration project were to test pricing as a method of managing congestion on the general-purpose freeway lanes, managing demand on the HOV lanes, expanding transit and rideshare services in the corridor, and enhancing air quality in the region.

The initial demonstration project and the ongoing HOT project represent the joint efforts of the San Diego Council of Governments (SANDAG), Caltrans, the Metropolitan Transit Development Board (MTDB), and CHP. SANDAG is responsible for overall project management, Caltrans operates the HOV lanes, MTDB operates bus service in the corridor, and CHP is responsible for enforcement.

The initial demonstration project, ExpressPass, began in 1996. Under the pricing project, the operating hours were extended to 5:45 a.m. to 11:00 a.m. in the southbound direction and Noon to 7:00 p.m. in the northbound direction Monday through Friday. The lanes are open northbound from Noon on Friday to 5:00 a.m. on Monday. There is one entrance and one exit to the HOV facility. During this phase, a limited number of monthly permits were sold to motorists on a first-come, first-serve basis. Drivers with permits could use the lanes without meeting vehicle-occupancy requirement, while carpools, vanpools, and buses continued to use the lanes for free. The monthly fee was first set at $50 in December 1996 and 500 permits were sold. In 1997, the permits issued and the fee increased to 700 and $70, respectively. A permit waiting list of between 200 and 600 individuals existed over the course of this phase.

In April 1999, the FasTrak™ phase was implemented with electronic toll collection replacing the monthly passes. Variable fees for single-occupancy vehicle use of the HOV lanes are collected electronically. The fee depends on the congestion level in the HOV lanes and is recalculated each six minutes to maintain a level-of-service C. Fees typically range from $0.50 to $4.00 according to the time-of-day relative to traffic peaks, although the fee could reach as high as $8.00. Message signs located before the start of the lanes display the updated fee. The following elements highlight some of the ongoing monitoring and evaluation efforts on the I-15 Express Lanes.

- **I-15 FasTrak™ Customer Service Center**. The FasTrack Customer Service Center maintains monthly summaries of FasTrack account activity. Items tracked include FasTrack application requests, complaints/comments, and account maintenance. The status of accounts are monitored, including the total number of accounts and the number opened and closed during the year. The total number of transponders issued, the number issued and returned during the year, and the number in the inventory are also documented on a monthly basis. A log of customer comments is maintained.
- **Average Daily Traffic and Toll Revenues**. Data on vehicle volumes on the I-15 Express Lanes are obtained through inductive loops. FasTrak™ records daily toll revenues. The weekday daily average for all vehicles and for HOVs, FasTrak™ vehicles, and tags with invalid reads are summarized on a monthly basis. This information is presented in table format for each day of the month and the monthly totals by year are summarized in a graph.
- **Enforcement**. CHP provides enforcement on the I-15 Express Lanes. CHP maintains a monthly log of the enforcement levels – hours allotted and hours worked by officers in patrol cars and motorcycles – and the number of citations and verbal warnings issued. This information is presented in table and graph formats on a monthly basis.
- **Telephone Survey**. In the fall of 1997, a telephone survey was conducted of 1,500 commuters in the San Diego area to obtain information on travel modes, perceptions about the I-15 HOV lane, and the ExpressPass program. A total of 500 ExpressPass customers were included in the survey. The responses from ExpressPass customers indicated strong support for the program. Other commuters in the I-15 corridor responded that the program was fair to users and non-users.
- **I-15 FasTrak Patron Survey**. In January 2005, SANDAG mailed a survey to 18,000 FasTrak™ customers. The survey contained three questions relating to use of the FasTrak™ Customer Service Center. Slightly over 3,000 surveys were received, accounting for a 17 percent response rate.

Other elements of the ongoing assessments include monitoring the use of park-and-ride lots, monitoring bus ridership levels, and an attitudinal panel survey. These efforts and other activities were conducted by personnel from San Diego State University, the University of California, Irvine, and consulting firms.

APPENDIX A – REFERENCES AND ADDITIONAL RESOURCES

This appendix contains the references used in the handbook. It also provides additional resources related to topics associated with HOV performance monitoring, evaluating, and reporting.

CHAPTER TWO – EXECUTIVE SUMMARY

The following references provide a national overview of the benefits and use of HOV lanes. References on the other topics covered in the chapter are provided in the specific chapters.

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CHAPTER SIX – DATA REDUCTION AND ANALYSIS TECHNIQUES

Texas Transportation Institute, Parsons Brinckerhoff Quade and Douglas, and Pacific Rim Resources. *HOV Systems Manual*. National Cooperative Highway Research Program Report 414. Transportation Research Board, Washington, D.C., 1998.

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APPENDIX B – GLOSSARY OF TERMS

This appendix contains a glossary of terms associated with HOV performance monitoring, evaluation, and reporting. It focuses on terms used in the handbook. The glossary is based on the glossaries for the NCHRP HOV Systems Manual and the AASHTO Guide for High-Occupancy Vehicle Facilities.

Advanced Traffic Management System (ATMS): Remotely operated traffic management system for monitoring and managing operations of a freeway system including HOV lanes and arterial streets. Major elements of the system include surveillance, communications, and controls.

Articulated Bus: An extra-long, high-capacity segmented bus that has the rear portion flexible but permanently connected to the forward portion with no interior barrier to hamper movement between the two parts. The seated passenger capacity is 60 to 80 persons with space for many standees, and the length is from 160 to 70 ft. The turning radius for an articulated bus is usually less than that of a standard urban or intercity bus.

At-grade Access: Ingress/egress between an HOV facility and the adjacent general-purpose lanes that occurs with a direct merging maneuver. Contrast with Direct (Grade-separated) Access Ramps.

Auto Free Zone: An area, usually within a densely developed corridor, where all autos or all motorized vehicles are banned.

Automated Vehicle Identification (AVI): Use of overhead or roadside detectors to read and identify vehicles equipped with a transponder or similar device. Used for electronic toll collection and traffic management.

Automatic Vehicle Location (AVL): The use of advanced technologies such as global positioning systems (GPS) to monitor the location and movement of vehicles.

Average Vehicle Occupancy (AVO): The number of people divided by the number of vehicles (including buses) traveling past a specific point over a given time period.

Barrier-separated HOV Facility: A roadway or lane(s) built within the freeway right-of-way that is physically separated by barriers or pylons from other freeway lanes and is designated for the exclusive use of high-occupancy vehicles during at least portions of the day. These facilities can operate as reversible flow (i.e., inbound in the morning and outbound in the evening) or two-way (i.e., one or more lanes operating in each direction).

Benefit-cost Ratio (B/C): The ratio of the dollars of discounted benefits achievable to a given outlay of discounted costs.

Buffer Separation: A roadway area that is used to separate an HOV lane from a general-purpose lane.

Bus: A self-propelled, rubber-tired road vehicle designed to carry a substantial number of passengers, commonly operated on streets and highways. A bus has enough head room to allow passengers to stand upright after entering.

Bus Malls: Bus or transit streets that are reserved exclusively for use by public transit vehicles.

Bus Priority System: A system of traffic controls in which buses are given special advantages over other mixed-flow traffic (e.g., preemption of traffic signals or preferential lanes).

Bus Rapid Transit (BRT): While a precise definition of BRT is elusive, it is generally understood to include bus services that are, at a minimum, faster than traditional "local bus" service and, at maximum, include grade-separated bus operations. Essential features of BRT systems are some form of bus priority, faster passenger boarding, faster fare collection, and a system image that is uniquely identifiable.

Busway / HOV Facility in Separate Right-of-Way: A roadway or lane(s) developed in a separate right-of-way and designated for the exclusive use of high-occupancy vehicles (commonly buses only).

Capacity, Design (or roadway capacity): The maximum number of vehicles (vehicle capacity) or persons (person capacity) that can pass over a given section of roadway in one or both directions during a given period of time under prevailing environmental, roadway, and roadway user conditions, usually expressed as vehicles per hour or persons per hour. Operational capacity for an HOV lane should be less than this.

Carpool: Any vehicle (usually a private automobile) or arrangement in which two or more occupants, including the driver, share the use, cost, or both traveling between fixed points on a regular basis.

Central Business District (CBD): That portion of a city which serves as the primary activity center. Its use is characterized by intense business activity that serves as a destination for a significant number of daily work trips.

Clean Air Act Amendments of 1990 (CAAA): Federal legislation that establishes new requirements in metropolitan areas and states where National Ambient Air Quality Standards (NAAQS) attainment could be a problem.

Commute Trips: Trips that are taken on a daily or regular basis to work.

Concurrent Flow HOV Facility, Buffer-separated: A non-physically separated lane(s) containing buffer separation that is oriented to operate in the same direction as the adjacent general-purpose lanes. The facility is commonly the inside lane(s) of the freeway cross section, adjacent to the median barrier, and it is designated for the exclusive use of HOVs during at least portions of the day.

Concurrent Flow HOV Facility, Non-separated: A designated lane containing no buffer separation with the adjacent general-purpose lanes and oriented to operate in the same direction as the adjacent general-purpose lanes. The facility is commonly the inside lane and adjacent to the median barrier. Non-separated facilities commonly serve HOVs during portions of the day, reverting to a general-purpose lane during other periods.

Congestion Pricing: The policy of charging drivers a fee that varies with the level of traffic on a congested roadway. Congestion pricing is designed to allocate roadway space, a scarce resource, in a more economically feasibly manner.

Contraflow HOV Facility: A designated freeway lane or lanes (commonly the inside lane in the off-peak direction of general-purpose travel) designated for exclusive use by HOVs traveling in the peak direction during peak commuting periods. The lane is usually separated from the off-peak direction general-purpose lanes by a moveable barrier or plastic pylons.

Corridor: A broad geographical band that identifies a general directional flow of traffic. It may encompass streets, highways, and transit route alignments.

Cost-benefit Analysis: An analytical technique that compares the societal costs and benefits (measured in monetary terms) of proposed programs or policy actions. Identified losses and gains experienced by society are included, and the net benefits created by an action are calculated. Alternative actions are compared to allow selection of one or more that yield the greatest net benefits or benefit-cost ratio.

Deadheading: Segment of a trip made by a transit vehicle not in revenue service.

Delay: The increased travel time experienced by a person or vehicle due to circumstances that impede the desirable movement of traffic. It is measured as the time difference between actual travel time and free-flow travel time.

Department of Transportation (DOT): State agency responsible for administering federal and state highway funds.

Diamond Symbol: A uniform traffic control symbol used on signing and pavement markings to designate the restricted usage on HOV facilities.

Differential Pricing (Variable Pricing): Time-of-day pricing and tolls that vary by other factors like facility location, season, day-of-week, or air quality impact.

Direct (Grade-separated) Access Ramps: Ramps that provide ingress/egress between HOV facilities and support facilities or cross streets. Ramps of this type include flyover ramps, freeway-to-freeway direct connections, drop ramps, or T-ramps. Contrast with At-grade Access.

Directional Split: The distribution of traffic flows on a two-way facility.

Drop Ramp: This direct (grade-separated) access ramp design gets its name because it "drops" to the HOV facility from a cross street.

Dynamic Pricing: Tolls that vary in response to changing congestion levels, as opposed to variable pricing that follows a fixed schedule.

Electronic Toll Collection (ETC): This refers to electronic systems that collect vehicle tolls, reducing or eliminating the need for tollbooths and for vehicles to stop.

Emergency Vehicle: Any vehicle generally used in responding to an incident that has caused or may lead to life or injury threatening conditions or destruction of property. Examples are police, fire, and ambulance vehicles as well as tow trucks and maintenance vehicles.

Enforcement: The function of maintaining the rules and regulations to preserve the integrity of an HOV facility.

Federal Highway Administration (FHWA): Part of the U.S. Department of Transportation. FHWA is responsible for administering all federal-aid highway programs.

Federal Transit Administration (FTA): Formerly the Urban Mass Transportation Administration, part of the U.S. Department of Transportation. FTA is responsible for administering all federal-aid public transportation programs.

Flyover Ramp: This ramp design accommodates direct, high-speed connections between the general-purpose freeway lanes, park-and-ride lot, or other roadway with the HOV lane. These ramps get their name because they "fly over" the roadway to provide direct ingress/egress.

Freeway-to-freeway Direct HOV Connections: A ramp that provides a direct connection at the interchange of an HOV facility within one freeway right-of-way to an HOV facility within another freeway.

General-purpose Lanes: Travel lanes which are open to all vehicle types and/or occupancy levels along the roadway.

High-occupancy Toll (HOT) Lanes: HOV facilities that allow lower-occupancy vehicles, such as solo drivers, to use these facilities in return for toll payments, which could vary by time of day or level of congestion.

High-occupancy Vehicle (HOV): Motor vehicles carrying at least two or more occupants including the driver. An HOV could be a transit bus, vanpool, carpool, or any other vehicle that meets the minimum occupancy requirements, usually expressed as either two or more, three or more, or four or more persons per vehicle.

High-occupancy Vehicle (HOV) Lane: An exclusive traffic lane or facility limited to carrying high-occupancy vehicles (HOVs) and certain other qualified vehicles.

High-occupancy Vehicle (HOV) System: The collective application of physical facilities to support HOV operations, including HOV lanes, park-and-ride lots, park-and-pool lots, and/or other supporting facilities that are administered so as to effectively integrate all physical elements into a unified whole.

Ingress/Egress: The provision of access to/from an HOV or park-and-ride facility.

Inherently Low Emission Vehicles (ILEV): Alternative fueled clean air vehicles. Related terms include Zero-Emission vehicles (ZEVs), Ultra-Low-Emission (ULEV), and Super-Ultra-Low-Emission (SULEV) vehicles powered by alternative fuels.

Intelligent Transportation Systems (ITS): Advanced technologies and communication systems. In this guide, their application is to provide a remotely operated system for monitoring and managing the operation of an HOV and/or freeway facility to better assure acceptable traffic operation and improved responsiveness to incidents. Major elements are (a) surveillance—collection and processing of data by detectors and visible verification by closed circuit television, toll tags, or inductance loops; (b) communications—presentation of operational information to motorists through signs, delineation, signals, and/or auditory means; and (c) control—application of traffic restraints or direction of flow by signs, barrier gates, and signals.

Intermodal Facilities: Locations that allow travelers to change between transportation modes.

Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA): Federal legislation that mandated the way transportation decisions were made and funded over fiscal years 1992-1997. The Transportation Equity Act for the 21st Century was enacted June 9, 1998, as Public Law 105-178. TEA-21 authorizes the Federal surface transportation programs for highways, highway safety, and transit for the 6-year period 1998-2003.

Level of Service (LOS): A descriptive measure of the quality and quantity of transportation service provided the user that incorporates finite measures of quantifiable characteristics such as travel time, travel cost, number of transfers, etc. Operating characteristics of levels of service for motor vehicles can be found in the latest edition of the *Highway Capacity Manual*.

Line Haul: That portion of commute trip that is express (non-stop) between origin and destination.

Local Bus Service: Bus routes and service characterized by frequent stops and slow operating speeds.

Mode Shift: The shift of people from one mode to another (i.e., SOVs to HOVs).

National Environmental Policy Act (NEPA): Legislation enacted in 1969 that requires federally funded projects to conduct an environmental impact study (EIS) to evaluate potential impacts.

National Highway System (NHS): Interstate highways and other roads designated as important for interstate travel, national defense, intermodal connections, and international commerce.

National Intermodal Transportation System (also known as National Transportation System): Integrated system connecting major transportation facilities.

Nonattainment Area: A geographic area in which the level of a criteria air pollutant is higher than the level allowed by the NAAQS.

Off-line Station: A transit station that provides safe and sheltered locations for passengers to board buses or transfer between different bus routes or services, which is located adjacent to the freeway or at a point farther away from the HOV lane facility (contrast location with On-line Station).

Off-peak Direction: The direction of lower demand during a peak commuting period. In a radial corridor, the off-peak direction has traditionally been away from the CBD in the morning and toward the CBD in the evening.

On-line Station: A transit station that provides a safe and sheltered location for passengers to board buses or transfer between different bus routes or services, which is located directly along an HOV lane (contrast location with Off-line Station).

Paratransit Vehicle: Any form of intraurban demand-responsive vehicle such as taxis, carpools, etc., that are available for hire to the public. They are distinct from conventional transit as they generally do not operate on a fixed schedule.

Park-and-ride (P&R) Lot: A parking facility where individuals access public transportation as a transfer of mode, usually from their private automobiles. Public transportation usually involves express bus from the lot to a central business district or major activity center.

Park-and-Pool Lot: A parking facility where individuals rendezvous to use carpools and vanpools as a transfer of mode, usually from their private automobiles. The facility is not served by public transportation.

Peripheral P&R Lot: A facility that provides additional parking for businesses and land uses primarily surrounding the lot or in proximity. These facilities may be unintentional consequences of poor facility location. They may be served by high levels of transit, but productivity measured by transit ridership from the lot may be low.

Remote Long-distance P&R Lot: Lots located at greater distances from the primary activity center than the traditional suburban P&R lot. These facilities will often be located at the center of a smaller activity center, but provide parking and transit service to the distant primary center.

Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU): Authorizes federal surface transportation programs for highways, highway safety, and transit for 2005-2009.

Satellite Parking Facilities: Park-and-ride lots placed on the perimeter of the primary activity center or central business center. These facilities are designed to provide relatively inexpensive parking for commuters accessing the activity center without having to travel into the center. These facilities may be served by transit.

Suburban P&R Lot: Park-and-ride lot typically located in outer portions of the urban area, primarily serving commute-to-work travel between the suburbs and the central city or other major activity center. Transit services may be extensive, with routes provided to multiple locations. Alternatively, more restricted transit providing service only to the primary business center within the region may be offered.

Peak Direction: The direction of higher demand during a peak commuting period. In a radial corridor, the peak direction has traditionally been toward the central business district in the morning and away from the central business district in the evening.

Peak Hour: That hour during which the maximum demand occurs for a given transportation corridor or region, generally specified as the morning peak hour or the evening peak hour.

Peak Period: A portion of the day in which the heaviest demand occurs for a given transportation corridor or region, usually defined as a morning or evening period of two or more hours.

Preferential Parking: Parking lots or spaces reserved exclusively for HOVs only as a means to encourage ridesharing. They are usually located closer to a terminal or building entrance than other vehicle spaces and may also have a reduced parking fee.

Preferential Treatment: In transportation, giving special privileges to a specific mode or modes of transportation (i.e., bus lanes or signal preemption at intersections).

Price Elasticity of Demand: A measure of the sensitivity of demand for a commodity to a change in its price. It equals the percentage change in consumption of the commodity that results from a 1-percent change in its price. The greater the elasticity, the more price-sensitive the demand for the commodity.

Priority Lane: Lane providing preferential treatment to eligible vehicles.

Priority Lane Pricing: Concept of using congestion pricing on an HOV lane.

Public Transit (or Public Transportation): Passenger transportation service to the public on a regular basis using vehicles that transport more than one person for compensation, usually but not exclusively over a set route or routes from one fixed point to another. Routes or schedules of this service may be predetermined by the operator or may be determined through a cooperative arrangement.

Queue: A line of waiting vehicles or persons. For example, traffic at a bottleneck location or signal, or buses at a park-and-ride facility, or persons in line to board a bus.

Queue Bypass HOV Facility: A short, often non-separated lane, designated to operate in the same direction as the adjacent general-purpose traffic lanes through an isolated traffic bottleneck, a toll plaza, or a metered location. The lane is designated for the exclusive use of HOVs and provides a "head-of-the-line" advantage in bypassing queued traffic.

Ramp Meter Bypass: A form of preferential treatment in which bypass lanes are provided at a ramp meter for the exclusive use of HOVs.

Ramp Metering: A system used to reduce congestion on a freeway facility by managing flow from on-ramps. An approach ramp is equipped with a metering traffic signal that allows the vehicles to enter a facility at a controlled rate.

Reversible Lane: A lane on which the direction of traffic flow can be changed to utilize maximum roadway capacity during peak demand periods.

Ridesharing: The function of sharing a ride with other passengers in a common vehicle. The term is usually applied to carpools and vanpools.

Road Pricing: An umbrella phrase that covers all charges imposed on those who use roadways. The term includes such traditional revenue sources as fuel taxes and license fees as well as charges that vary with time of day, the specific road used, and vehicle size and weight.

Signal Preemption: A technique for altering the sequence or duration of traffic signal phasing using vehicle detection in order to provide preferential treatment for buses and emergency vehicles.

Signal Priority: Technique of altering the sequence or timing of traffic signal phases using special detection in order to provide preferential treatment.

Single-occupant Vehicle (SOV): Any vehicle carrying only the driver.

Slip Ramp: A type of at-grade access that can be used at the beginning or end of an HOV facility that provides an acceleration/deceleration taper.

Spot HOV Treatments: Techniques that may be used to give HOVs priority around a specific bottleneck or with special access to a facility.

Study Period: The time during which a study is being conducted, which could be one or more parts of a day, all day, or more than a day.

Supporting Facilities: Facilities that provide for the safe and sheltered transfer of passengers between different travel modes, bus routes or services. General types of these facilities include park-and-ride and park-and-pool lots, transit stations, intermodal facilities, and bus stops and shelters.

Time-of-Day Pricing: Facility tolls that vary by time of day in response to varying congestion levels. Typically, such tolls are higher during peak periods when the congestion is most severe.

Toll Road: A road where motorists are charged a use fee (or toll). Toll roads may have preferential pricing for HOVs.

T-ramp: This direct (grade-separated) access ramp design gets its name because it forms the letter “T” between the HOV lane and the connecting park-and-ride lot or cross street.

Transit Center (or Transit Station): A mode transfer facility serving transit buses and other modes such as automobiles and pedestrians. In the context of this document, transit centers can provide premium park-and-ride services, allowing passengers to connect with a number of transit routes and other services.

Transit, Light Rail (LRT): An urban railway system characterized by its ability to operate single cars or short trains in streets or exclusive right-of-way, capable of discharging passengers at track or car floor level.

Transponder: An electronic tag mounted on a license plate, built into a vehicle, or placed on the dashboard. The tag is read electronically by an electronic tolling device that automatically assesses the amount of the user fee.

Transportation Control Measures (TCM): A general term referring to transportation demand management (TDM), transportation systems management (TSM), and technology improvements that can be used to reduce regional emissions within a nonattainment area.

Transportation Demand Management (TDM): The operation and coordination of various transportation system programs to provide the most efficient and effective use of existing transportation services and facilities. TDM is one category of TSM actions.

Transportation Equity Act for the 21st Century (TEA-21): The Transportation Equity Act for the 21st Century was enacted June 9, 1998 as Public Law 105-178. TEA-21 authorizes the Federal surface transportation programs for highways, highway safety, and transit for the 6-year period 1998-2003.

Transportation System Management (TSM): Actions that improve the operation and coordination of transportation services and facilities to affect the most efficient use of the existing transportation system. Actions include operational improvements to the existing transportation system, new facilities, and demand management strategies.

Travel Time: The length of time it takes to travel between two points.

Travel Time Reliability: Term referring to the lack of variability in travel time that can be expected using different facilities.

Travel Time Savings: Time saved by using an HOV facility rather than the general-purpose lanes.

Value Pricing: A system of fees or tolls paid by drivers to gain access to dedicated roadway facilities providing a superior level of service compared to the competitive free facilities. Value pricing permits anyone to access the managed lanes, and the value of the toll is used to ensure that the management goals of the facility are maintained.

Vanpool: A prearranged ridesharing function in which a number of people travel together on a regular basis in a van, usually designed to carry six or more persons.

Violation Rate: The total number of violators divided by the total number of vehicles in HOV lane(s).

Volume to Capacity Ratio: The ratio of demand flow rates to capacity for a given type of transportation facility.

APPENDIX C – LIST OF ABBREVIATIONS

AASHTO: American Association of State Highway and Transportation Officials

ADA: Americans with Disabilities Act

ATMS: Advanced Traffic Management System

AVC: Automatic Vehicle Classification

AVI: Automated Vehicle Identification

AVL: Automatic Vehicle Location

AVO: Average Vehicle Occupancy

B/C: Benefit-cost Ratio

BRT: Bus Rapid Transit

CBD: Central Business District

CCTV: Closed-circuit Television

CMAQ: Congestion Mitigation and Air Quality Program

DMS: Dynamic Message Signs

DOT: Department of Transportation (State or Federal)

EPA: Environmental Protection Agency

ETC: Electronic Toll Collection

FHWA: Federal Highway Administration

FTA: Federal Transit Administration

GIS: Geographic Information System

HCM: Highway Capacity Manual

HOT: High-occupancy Toll

HOV: High-occupancy Vehicle

ILEV: Inherently Low Emission Vehicle

ISTEA: Intermodal Surface Transportation Efficiency Act

ITMS: Integrated Transportation Management Systems

ITS: Intelligent Transportation Systems

LOS: Level-of-service

LRT: Light Rail Transit

MOE: Measures of Effectiveness

MPH: Miles Per Hour

MPO: Metropolitan Planning Organization

MUTCD: Manual on Uniform Traffic Control Devices

NAAQS: National Ambient Air Quality Standards

NCHRP: National Cooperative Highway Research Program

NHS: National Highway System

NEPA: National Environmental Policy Act

P&P: Park-and-pool

pphpl: Persons per Hour per Lane

P&R: Park-and-ride

ROW: Right-of-way

RRT: Rail Rapid Transit

SAFETEA-LU: Safe, Accountable, Flexible, and Efficient Transportation Equity Act – A Legacy for Users

SOV: Single-Occupant Vehicle

TCM: Transportation Control Measure

TCRP: Transit Cooperative Research Program

TDM: Transportation Demand Management or Travel Demand Management

TEA-21: Transportation Equity Act for the 21st Century

TRB: Transportation Research Board

TSM: Transportation Systems Management

VMT: Vehicle Miles Traveled

vph: Vehicles per Hour

vphpl: Vehicles per Hour per Lane

APPENDIX D – AGENCY CONTACTS

The following agencies are participating in the HOV Pooled-Fund Study. The point of contact is listed for each agency.

Agency	Point of Contact	Telephone
California Department of Transportation	Tim Buchanan	916-654-6448
Georgia Department of Transportation	Daryl Cranford	404-656-5360
Tennessee Department of Transportation	Donald Dahlinger	615-741-3033
Virginia Department of Transportation	Chris Detmer	804-786-3599
Maryland State Highway Administration	Terrance Hancock	410-545-5675
Washington State Department of Transportation	Mark Leth	206-440-4487
Massachusetts Highway Department	Ken Miller	617-973-8064
New Jersey Department of Transportation	Laine Rankin	609-530-6539
Minnesota Department of Transportation	Nick Thompson	651-634-5310
New York Department of Transportation	Wayne Ugolik	631-952-6108

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