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guide for high-occupancy  
vehicle facilities

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# GUIDE FOR HIGH-OCCUPANCY VEHICLE (HOV) FACILITIES

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Prepared by the  
**Technical Committee on Public Transportation Facilities Design**  
AASHTO Subcommittee on Design

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# Introduction

Limited right-of-way and economic realities often dictate that public investments be concentrated toward increasing the efficiency of and preserving the existing transportation infrastructure rather than expanding the existing transportation infrastructure. At the same time, it is likely that growth of metropolitan areas will continue. A major consequence of these trends will be an increasing inability of the existing transportation system to meet future demand. Therefore, alternative measures must be taken to prioritize use, such as moving more people in fewer vehicles.

Various transportation systems management (TSM) tools are available to help achieve increased traffic efficiency on existing transportation systems. Typical examples of TSM tools are: traffic operations improvements at intersections, operational improvements on freeways, improved signalization, and street system controls (one-way streets or reversible lanes).

This guide suggests methods and designs for dedicated facilities to encourage greater use of existing transportation systems, such as increased use of public transit (primarily buses), carpools, vanpools, or other ridesharing modes to help attain the above goals. Guidance is given for planning and design of preferential treatment for high-occupancy vehicles (HOVs). Portions of this guide have been excerpted from the previous edition of this guide, which this new guide replaces (3), the National Cooperative Highway Research Program (NCHRP) *HOV Systems Manual* (56), and recent research from Texas (18).

This guide has been developed to help achieve the following goals of HOV facilities:

- To provide travel-time savings and travel-time reliability for HOVs;
- To maximize the person-moving capacity of roadway facilities by providing improved operating level of service for HOVs, both public and private; and
- To conserve fuel, improve air quality, and minimize consumption of other resources needed for transportation.

HOV lanes may be provided on freeways and other roadways for the exclusive use of buses and other HOVs so they can bypass peak-period congestion on the general-purpose lanes. Increases in ridesharing can be gained from this option when the time savings are significant. The guide discusses a number of options for the establishment of HOV accommodations.

HOV facilities are usually incorporated into existing highway rights-of-way where width and lateral clearances may be limited. While experience has shown that some variance in design is possible without serious adverse effects on safety and performance, the experiences have not been extensive enough to firmly establish new standards specifically for these types of facilities. Therefore, the values presented in this guide should not be regarded as absolute, but rather as the best guidance available based on experience to date.

## OVERVIEW OF GUIDE

This guide is intended as just that—a guide. Where this guide does not provide specific geometric information, please refer to *A Policy on Geometric Design of Highways and Streets* (5) for guidance. In some chapters, this guide provides desirable and minimum cross sections and design criteria. Prior to implementing designs that are less than the minimums, an engineering review should be completed with respect to the safety and operational impacts of these geometric elements and their justification. For minimum designs, the designer should review Section 2.1, which describes the link between design, operations, and enforcement of HOV facilities to better understand the conditions under which the minimum designs might

be appropriate and what operational treatments might be necessary. The Federal Highway Administration (FHWA), Federal Transit Administration (FTA), state Department of Transportation (DOT), transit agency, city, and others should agree on the most appropriate cross-section and other geometric design elements. A formal design exception request may need to be processed to document the decisions and their approvals.

The guide also has a glossary to acquaint the reader with certain expressions and terminology that are used in this guide. The five chapters in the guide are described below.

## **Chapter 1—Planning for Freeway and Arterial HOV Facilities**

For an HOV facility to be successful, a number of early assessments and commitments must be made. Chapter 1 identifies those initial considerations that are critical to assuring an efficient and effective HOV operation.

Chapter 1 also describes HOV lane planning issues. The planning section includes an overview of the process, planning for facilities on freeways and arterials, public involvement, and planning for implementation and evaluation.

## **Chapter 2—Operating and Enforcing HOV Facilities on Freeways**

Chapter 2 of the guide describes operational and enforcement considerations for implementation of a successful freeway HOV facility. The operational issues that are described include consideration of the design during decision-making regarding operations and enforcement, selection of eligible vehicles, hours of operation, incident management, and pricing issues.

## **Chapter 3—Design of HOV Facilities on Freeways**

Chapter 3 includes the various types of HOV facilities that may be used in conjunction with freeway sections. These facilities include HOV facilities in separate rights-of-way, barrier-separated facilities (reversible or two-way), concurrent flow lanes, and contraflow lanes. HOV queue bypass lanes for HOVs are discussed, as well as online transit stations. A separate section on signing and pavement markings is provided. Design considerations such as example cross sections and schematics are provided for each facility type. A general section at the beginning of Chapter 3 describes various design features applicable to many HOV facility types.

## **Chapter 4—Operating and Enforcing HOV Facilities on Arterial Streets**

Chapter 4 provides information related to the operation and enforcement of HOV facilities on arterial streets. This chapter describes topics such as conceptual alternatives for arterial HOV facilities, vehicle eligibility, operating hours, enforcement, and intersection control, driveway access, and curb-use considerations.

## **Chapter 5—Design of HOV Facilities on Arterial Streets**

The material presented in Chapter 5 is intended to serve as a guide for the design of HOV facilities on arterial streets. This guidance includes geometric design and also traffic-control aspects for arterial HOV facilities.

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# Chapter 1

## Planning for Freeway and Arterial HOV Facilities

This chapter provides an overview of the steps involved in planning HOV lanes in separate rights-of-way, on freeways, and on arterial streets. It presents approaches for regional-, corridor-, and facility-level planning; tools and techniques for demand estimation; and approaches for assessing environmental benefits and impacts. Portions of this chapter have been excerpted from the NCHRP *HOV Systems Manual* (56). This chapter is divided into the following sections:

- **Overview of the Planning Process.** This section provides an overview of the metropolitan transportation planning process, general concepts associated with planning HOV lanes, and agencies and groups normally involved in planning HOV lanes.
- **Planning HOV Lanes on Freeways and Arterials.** This section covers planning for HOV lanes at the regional, corridor, and facility level; elements of the planning process for these facilities; and examples of studies, techniques, and analytical tools.
- **Additional Planning Considerations.** This section outlines several special elements that should be included in the planning process, including the link to design, operation, and enforcement in planning; planning for new HOV lanes prior to full utilization; priority pricing; general design and cost factors; transit planning; commercial vehicle use; environmental impacts; lane conversion; and planning public involvement.
- **Planning for Implementation and Evaluation.** An introduction of implementation and evaluation, both of which need to be considered in the planning stages, is provided in this section.

### 1.1 OVERVIEW OF THE PLANNING PROCESS

#### 1.1.1 Groups Involved in Planning HOV Lanes

A number of agencies and groups should be involved in the planning process for HOV facilities. These groups should remain involved in all subsequent aspects of the HOV lane development. Table 1-1 highlights the typical roles and responsibilities of each group. Practitioners can use this information as a guide to help ensure that consideration has been given to including the appropriate groups in the planning process. Specific agencies and individuals may vary by area and by the type of facility being considered.

#### 1.1.2 General Transportation Planning Concepts

The transportation planning process focuses on developing a safe, efficient, and effective system for the movement of people and goods. Environmental and quality-of-life considerations are also important components of the planning process. The following concepts are often part of the transportation planning process and are connected to related objectives. Section 1.4 provides further examples of typical objectives and related measures of effectiveness (MOEs) (5).

- **Mobility.** The transportation system should enhance traveler mobility, providing the opportunity to reliably move from location to location when and by the mode travelers desire. Increasing congestion levels limit mobility in many metropolitan areas today.

**TABLE 1-1. Agencies and Groups Involved in Planning HOV Lane Facilities**  
(Adapted from Reference 56).

| Agency or Group                                                                                        | Potential Roles and Responsibilities                                                                                                                                                                                                                                                                                                                                                                  |
|--------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| State Department of Transportation (DOT)                                                               | <ul style="list-style-type: none"> <li>• Overall project responsibility on freeways and state-owned roads.</li> <li>• Responsible for planning process or assisting with planning.</li> <li>• Staffing multiagency team or participating on team.</li> <li>• Incident management planning.</li> </ul>                                                                                                 |
| Transit Agency                                                                                         | <ul style="list-style-type: none"> <li>• Overall project management with busways in separate rights-of-way.</li> <li>• Supporting role on freeway and arterial street projects.</li> <li>• Responsible for planning process or assisting with planning.</li> <li>• Bus operations planning.</li> <li>• Staffing multiagency team or participating on team.</li> </ul>                                 |
| Trucking Industry                                                                                      | <ul style="list-style-type: none"> <li>• Provide information on trucking origins and destinations.</li> <li>• Training of drivers for operating trucks on the facility.</li> </ul>                                                                                                                                                                                                                    |
| State and Local Police                                                                                 | <ul style="list-style-type: none"> <li>• Assist with planning process.</li> <li>• Lead role on planning for enforcement components.</li> <li>• Coordination with judicial personnel.</li> <li>• Participate on multiagency team.</li> <li>• Incident management planning.</li> </ul>                                                                                                                  |
| Local Municipalities                                                                                   | <ul style="list-style-type: none"> <li>• Identify transportation needs of community.</li> <li>• Overall project management with arterial street and traffic signal applications.</li> <li>• Support role with other HOV lane facilities.</li> <li>• Responsible for planning process or assisting with planning.</li> <li>• Staffing multiagency team or participating on team.</li> </ul>            |
| Rideshare Agency                                                                                       | <ul style="list-style-type: none"> <li>• Assist with planning rideshare components.</li> <li>• Participate on multiagency team.</li> </ul>                                                                                                                                                                                                                                                            |
| Metropolitan Planning Organization (MPO)                                                               | <ul style="list-style-type: none"> <li>• May lead regional HOV lane planning efforts or corridor studies.</li> <li>• Assist in facilitating meetings and multiagency coordination.</li> <li>• Ensure that projects are included in necessary planning and programming documents.</li> <li>• May have policies relating to HOV lane facilities.</li> <li>• Participate on multiagency team.</li> </ul> |
| Federal Agencies—<br>Federal Highway Administration (FHWA)<br>and Federal Transit Administration (FTA) | <ul style="list-style-type: none"> <li>• Funding support.</li> <li>• Overall approval of various steps.</li> <li>• Provide technical assistance.</li> <li>• Participate on multiagency team.</li> </ul>                                                                                                                                                                                               |
| Consultants and Contractors                                                                            | <ul style="list-style-type: none"> <li>• May be hired to conduct overall planning, alternatives analysis, or other studies or to coordinate the construction activities and schedules.</li> <li>• May staff or assist with multiagency teams.</li> </ul>                                                                                                                                              |

Continued

TABLE 1-1. *Continued*

| Agency or Group                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Potential Roles and Responsibilities                                                                                                                                                                                                                              |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Toll Authorities                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <ul style="list-style-type: none"> <li>• Assist with planning and implementing pricing components.</li> <li>• Lead or support role on planning for facility operations.</li> <li>• Lead or support role in planning for project funding and financing.</li> </ul> |
| Public Groups, including: <ul style="list-style-type: none"> <li>• Commuters and travelers.</li> <li>• General public, business, and neighborhood groups.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                    | <ul style="list-style-type: none"> <li>• Assorted project-related roles and responsibilities as they relate to the particular group.</li> </ul>                                                                                                                   |
| Other Groups, such as: <ul style="list-style-type: none"> <li>• Elected officials.</li> <li>• Judicial system: state and local courts.</li> <li>• Emergency Medical Services: fire and other emergency personnel.</li> <li>• Trucking operations.</li> <li>• Tow-truck operations.</li> <li>• Transportation management organizations.</li> <li>• Bicycle and pedestrian advocacy groups.</li> <li>• School districts.</li> <li>• Advocacy groups representing seniors.</li> <li>• Advocacy groups for the disabled.</li> <li>• Special user groups (e.g., taxi, limousine).</li> </ul> | <ul style="list-style-type: none"> <li>• Assorted project-related roles and responsibilities as they relate to the particular group.</li> </ul>                                                                                                                   |

Note: Depending on an area's institutional relationships, the roles and responsibilities may be different.

- **Safety.** The transportation system should allow for the safe movement of people and goods.
- **Efficiency.** Efficiency may relate to raising the average vehicle occupancy, providing direct routes to major activity centers, reducing freeway congestion, limiting access on freeways, providing facilities for bicycling and walking, and/or other techniques.
- **Multimodal and Intermodal Systems.** Providing connections among and between the various transportation modes and providing choices for travelers and commercial shippers represent important considerations during the planning process.
- **Land Use.** Land use and transportation are interconnected. The transportation system will influence land uses and development patterns, and land uses will also affect the transportation system. Assessing the interrelationship between the transportation system and land use is a major part of the planning process.
- **Environmental Considerations.** Planning considers the environmental impacts, including air quality, water quality, noise, and visual impacts, of the various alternatives. In air-quality nonattainment areas, transportation alternatives may be limited based on expected impacts.

- **Financing.** Most areas have limited resources available for transportation improvements; exploring alternative financing techniques may also be part of the planning process.
- **Economic Considerations.** The interrelationships between different transportation alternatives and economic development are often examined during the planning phase.

### 1.1.3 General Steps in Planning HOV Lanes

Figure 1-1 highlights the general steps in the planning process. Figure 1-1 shows how projects progress through the regional, corridor, and facility levels of planning through to final design, construction, operation, and evaluation. Figure 1-1 also shows how public involvement is present throughout all phases of project planning and design and construction. Section 1.2 of this guide describes the regional, corridor, and facility levels of planning, and Section 1.3 describes the additional planning considerations listed in Figure 1-1.

Project management teams should address the 11 major elements listed below when planning for any HOV lane facility. Some elements continue through the entire project, such as 1 and 3. The different elements can be applied to a particular corridor depending on the scope of work tasks, the type of facility

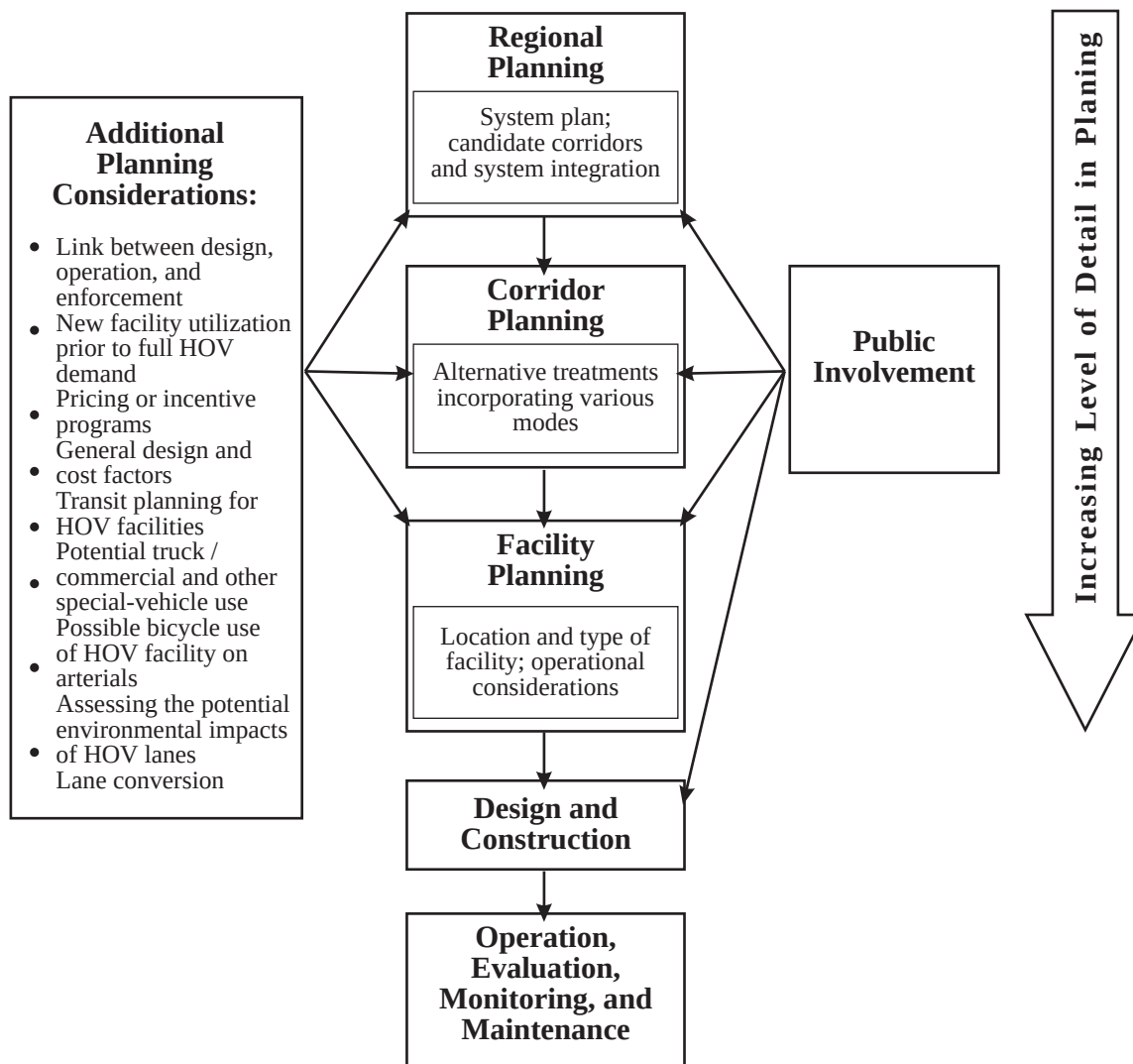


FIGURE 1-1. General Steps in Planning HOV Lanes.

being considered, the location characteristics, and related policy issues. The reader can find additional discussion of these planning elements in Chapter 4 of the *HOV Systems Manual* (56).

1. Identify and involve appropriate groups.
2. Identify issues and opportunities.
3. Initiate and continue public participation.
4. Identify objectives, analysis techniques, and data needs.
5. Identify alternatives.
6. Collect data.
7. Analyze alternatives.
8. Seek public input on alternatives.
9. Identify preferred alternative.
10. Conduct public review.
11. Select the preferred alternative.

The exact approach may be modified as needed for a specific freeway and/or arterial project or conditions. More detailed planning steps may be needed for complex corridors, while a simplified sketch-planning approach (see Section 1.2.4) may be used in other cases. The key for transportation professionals is to match the level of detail to the nature of the issues, characteristics of the area, and available resources.

## 1.2 PLANNING HOV LANES ON FREEWAYS AND ARTERIALS

As shown in Figure 1-1, planning for transportation improvements, including freeway and arterial HOV lanes, usually occurs at different levels. A broad regional planning effort is often undertaken first. This level focuses on the general needs, issues, and opportunities throughout a metropolitan area. The outcome is a long-range regional plan that identifies the general types of facilities anticipated in the major travel corridors and areas. However, regional plans do not usually define the exact type of treatment or design.

More detailed analyses are conducted in the planning process at the corridor and facility level. Planning at this stage is much more detailed and focuses on preliminary alternative design treatments, access options, vehicle-occupancy levels, and other issues. For example, a regional plan may identify the need for an HOV lane facility in a specific corridor, but the type of facility and the preliminary design would be examined in later planning phases.

Thus, planning for HOV lanes can be thought of as a cascading or funneling process. Planning at the regional scale focuses on identifying an overall system plan and the general types of facilities that may be appropriate. Planning at the corridor and facility level is more detailed, resulting in projects that can be taken forward into the design stage.

The operating environment on arterial streets is very different from freeway operations. Freeways serve long-distance, high-speed travel, with limited access points. Arterial streets serve short trips, provide access to local streets and land uses, and operate at relatively low speeds. Signalized intersections, driveway access, on-street parking, and interactions between passenger vehicles, transit, commercial vehicles, pedestrians, and bicyclists can all add complexity to the arterial street environment. These and other factors should be considered in planning, implementing, operating, and enforcing arterial street HOV lane facilities.

Arterial street HOV lane facilities are different from those found on freeways. Arterial street treatments typically provide priority to buses in downtown areas or other congested locations. Some applications include the use of the curb lane during the peak periods for buses and HOVs, queue jump treatments for

buses at busy intersections, and bus signal priority applications. A few longer-distance arterial street HOV lanes are currently in operation, and there is a growing interest in this approach in many areas. There is also interest in using arterial street facilities to link freeway HOV lanes to major activity centers.

While different in specifics, it is still important to consider both the regional and corridor connectivity between HOV lane facilities, whether freeway, arterial, or supporting infrastructure. Once a “big picture” view is considered for the proposed HOV lane facility, the general planning process for freeway applications would be appropriate for arterial street HOV lane facilities. Additional consideration should be given, however, to customizing the process to match the characteristics of the area and the type of project under consideration. For example, planning for addressing a bottleneck for buses at a signalized intersection will be simpler than the planning for a long-distance arterial HOV lane.

As noted earlier, the first step in the process should be the identification of the appropriate agencies, groups, and individuals to include in the planning effort. Depending on the ownership of the roadway and the type of project being considered, the state, local jurisdiction, or transit agency may have the lead responsibility for the planning process. Other agencies will play support roles.

Arterials serve places where people in the community interact, especially in areas with retail, restaurant, recreational, and educational uses. Local businesses, property owners, neighborhood groups, and representatives from special land uses like schools and hospitals should be involved early and throughout the planning process to ensure gathering places in the community are not affected by the HOV facility. These groups may have special concerns about on-street parking, access to businesses, delivery vehicles, and pedestrian and bicycle transportation needs. Identifying potential issues early in the planning process is critical to ensuring that they are adequately addressed and resolved.

The following sections provide an overview of the general approaches to planning HOV lane facilities at the regional, corridor, and facility levels. The various analytical tools and techniques commonly used in the planning process are also discussed.

### 1.2.1 Regional-Level Planning

The planning process for HOV facilities often begins at the regional level, and it focuses on the general needs, issues, and opportunities for transportation improvement within a metropolitan area. Planning for HOV facilities at the regional level may be part of the long-range transportation planning process conducted by an MPO, a special effort focusing on the development of a comprehensive HOV system, part of an air-quality conformance analysis, or other region-wide study. In any case, the planning process normally involves representatives from the MPO, the state DOT, the transit authority, local communities, the state police, and other groups. It is possible that an HOV lane proposal could begin as a project and evolve into a regional plan.

The regional planning process should also focus on a comprehensive system of HOV facilities that may include HOV lanes, busways, arterial street applications, park-and-ride lots, transit centers, bus and rideshare services, and other supporting policies and programs that fall logically together. The reader is encouraged to consult the American Association of State Highway and Transportation Officials (AASHTO) *Guide for Park-and-Ride Facilities* for design guidance of these facilities and to ensure park-and-ride facilities are designed for connectivity to the HOV system (7).

In a general case, the regional planning process aims to consolidate regional and local highway, street, and transit plans to make sure that the combination of projects selected best meets regional priorities. In most cases, regional-scale studies tend to focus on ensuring that the collective result of all proposed projects will result in a continuous network of highways, streets, or HOV lanes; an overall improvement in transit service times, coverage, or frequency; and/or the best overall ratio of benefits and costs (42).

The regional-level plan may include, but would not be limited to, the following items:

- Identify the goals and objectives of the region in the plan. These may include elements related to mobility, person-movement, air quality, and safety, and how the system of transportation improvements in the region will satisfy these goals and objectives. Example corridor and facility objectives are shown in Section 1.4.
- Develop a proposed 20-year plan for phased projects. Consideration should be given to preserving right-of-way and space to satisfy the design requirements of long-range projects at all levels of planning. Therefore, the plan will require updating by the agencies within the region. Policy and/or agreements within agencies and/or individuals within the region should also be included. The policy within each agency should also be included.
- Integrate HOV facilities into the plans and policies of the region. New HOV projects within the region should support each agency's strategic plan and also the MPO transportation plan.
- Correlate the influence of HOV system to the regional goals, objectives, and measures of effectiveness.
- Identify how support facilities and support services required for an HOV system can be integrated into policies, programs, and budgets of various agencies.
- Identify the analysis tools and techniques that are to be used. Often this includes the travel demand estimation from a regional model developed by the state DOT or the MPO. These models are usually based on the traditional four-step transportation process of trip generation, trip distribution, modal split, and route assignment. Therefore, the regional model should have HOV modeling capabilities. The regional model can be used to validate sketch-planning analysis (see Section 1.2.4) because the regional model will provide more detailed system analysis of HOV demand. More information on regional models can be found in Chapter 4 of the *HOV Systems Manual* (56).
- Identify considerations of access, facility type, design, enforcement, operation, and the environment appropriately for the unique conditions of the region. These considerations could vary by corridor or area within the region; however, system connectivity should be ensured.

Note the following national examples of regional long-range HOV system plans:

- HOV Lane/Managed Lane Study (San Diego Association of Governments);
- HOV System Plan for the Atlanta Metropolitan Region (Georgia Department of Transportation);
- Dallas Freeway HOV (2015) System Plan (Texas Department of Transportation);
- Los Angeles County HOV System Integration Plan (Los Angeles County Metropolitan Transportation Authority);
- Puget Sound High-Occupancy Vehicle Pre-Design Study (Washington Department of Transportation); and
- Toronto Regional HOV Plan (Ontario Ministry of Transportation).

### 1.2.2 Corridor-Level Planning

As shown in Figure 1-1, corridor-level planning follows regional planning. Greater detail is needed in the planning process for HOV facilities at the corridor level. At this stage, HOV treatments may be one of a number of possible improvements being considered. These alternatives may involve different alignments, including those on an existing freeway, arterial, or new right-of-way. Adding a general-purpose lane or a

mixed guideway transit line are just two examples of other alternatives that may be part of a corridor planning process. As indicated in the regional plan, it is important that consideration be given to preserving right-of-way and space to satisfy the design requirements of long-range projects at all levels of planning. Because corridor-level planning often includes the first assessments of locating HOV facilities (freeway and/or arterial), this section discusses locating HOV facilities, facility types, demand estimation, and operational techniques that may be used.

Planning at the corridor level may be undertaken as part of a corridor study. Corridor studies identify and evaluate appropriate improvements, including HOV lane facilities, and select the preferred alternative or alternatives. The MPO, state DOT, and transit agency have active roles in corridor studies. The lead agency should involve all of the affected agencies, however, and the corridor study should include a public participation process. The recommendations from a corridor study are incorporated into the Metropolitan/Regional Transportation Plans and Transportation Improvement Program developed by the MPO. It is important to consider that the items identified in bullet form in Section 1.2.1 as part of the regional plan should also be considered at the corridor level, especially if they had not been previously considered (i.e., there is no regional-level plan or policy in place).

The general elements of a corridor study are 1) defining the problems in the corridor, 2) developing realistic alternatives, and 3) evaluating these alternatives. The corridor study should include public involvement throughout all of these steps.

A full range of multimodal alternatives should be considered in the study. These alternatives should cover a range of approaches, costs, and benefits. The following examples provide a general indication of the types of alternatives that may be included in a corridor study:

- No-build or no-build plus transportation demand management (TDM) and/or transportation system management (TSM) alternatives;
- Highway-based alternatives;
- HOV lane alternatives;
- Bicycle and pedestrian facility improvement alternatives; and
- Transit fixed guideway alternatives.

The major part of a corridor study focuses on evaluating the identified alternatives. A variety of evaluation measures may be used to analyze and compare the alternatives. Possible criteria usually focus on the following general categories, with the specific MOEs directly related to the objectives of the project:

- Transportation system performance;
- Mobility and/or accessibility;
- Environmental and energy impacts;
- Cost and financial viability;
- Land-use and development impacts; and
- Equity and socioeconomic impacts.

Most corridor studies now include one or more HOV lane alternatives. The following are corridor-level studies that resulted in an HOV lane implementation:

- I-394, Minneapolis, Minnesota (Minnesota Department of Transportation);
- I-279, Pittsburgh, Pennsylvania (Pennsylvania Department of Transportation);
- I-93/Southeast Expressway, Boston, Massachusetts (Massachusetts Highway Department); and
- I-25 North Front Range, near Denver, Colorado (Colorado Department of Transportation).

### 1.2.2.1 Corridor Demand Estimation Techniques for Freeways and Arterial HOV Facilities

A number of models have been developed for estimating the demand for freeway HOV facilities at the corridor level. Some models evaluate parallel routes with the corridor under evaluation, some focus only on a single route, and others focus on a critical point along the route. Models have been created for several different geographical areas and/or conditions, including California (9, 68), Washington (developed by the Metropolitan Washington Council of Governments) (31), FHWA (41), and Texas (developed by the Texas Transportation Institute) (63).

Some of these techniques may be appropriate for use with arterial street projects. Although transit riders, bus operators, and carpools and vanpools may realize benefits from arterial street HOV lane facilities, arterial street treatments alone may not greatly influence mode shift in a corridor or region. As a result, estimating the demand for the new arterial HOV facility is often difficult. The paragraphs below describe the FHWA demand-estimation models.

*FHWA HOV Demand Model (1996).* The HOV demand-estimation model is a freeway sketch-planning methodology for predicting HOV lane and general-purpose lane demand and traffic performance, as well as limited environmental and energy impacts. The model uses the differences in travel times between the HOV and the general-purpose lanes and between before-and-after conditions as input to the demand estimation process. The model uses the differences in vehicle volumes in the HOV and the general-purpose lanes and between before-and-after conditions as the response to be predicted by the methodology (17).

*FHWA Methodology for Predicting Volumes for HOV Priority Treatments (1982) (41).* This methodology uses readily available traffic data to estimate modal changes resulting from implementing new HOV lane facilities. It is intended to provide a quick process since the data input is relatively minimal. The methodology is based upon quantitative analysis of before-and-after studies of several HOV lane facilities. From these data, the methodology predicts the traffic demand in the general-purpose and the HOV lanes.

Little analysis has been done on demand-estimation techniques with arterial street projects. The 1982 FHWA model has been the most widely used technique over the past 15 years. Although the model was developed for estimating the demand for freeway HOV lane facilities, it has been adapted for use with arterial street projects.

*Travel-Time Savings Estimation.* Large shifts of traffic to an HOV lane can cause a potential decline in the travel-time savings incurred in the HOV lane. Without the travel-time savings, there is a reduced incentive to commuters to use the HOV lanes. Estimating mode share demand is a function of the travel-time savings that commuters gain when traveling in the HOV lanes. Freeway speeds should be determined to estimate the potential travel-time savings of HOV lane alternatives. *The Highway Capacity Manual* can be used to obtain speed-flow relationships. Further information can be found elsewhere (9, 56, 58).

### 1.2.2.2 Freeway and Arterial Simulation Models

Several models can be used to simulate freeway and arterial HOV facilities. These microscopic and macroscopic simulation tools are described below.

*Verkehr in Städten Simulation (Traffic in Cities Simulation) (VISSIM)*. VISSIM is a microscopic computer traffic simulation model developed in Germany. VISSIM models vehicles, transit, bicycle, and pedestrian traffic flow, and it can be used for modeling HOV lane alternatives for arterials and freeways, as well as multimodal elements (47).

*AIMSUN (Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks)*. The AIMSUN traffic model is a microscopic model developed by the Universitat Politècnica de Catalunya and Transport Simulation Systems in Barcelona, Spain. AIMSUN can be used to model new traffic-control systems and management policies. AIMSUN can also be used to model traffic networks, including urban networks, freeways, highways, arterials, or combinations of these facilities (45, 57).

*PARAMICS (PARAllel MICroscopic Simulation)*. PARAMICS is another microscopic tool that can be used for modeling HOV lane alternatives. PARAMICS was originally developed by the Edinburgh Parallel Computing Centre located at the University of Edinburgh and SIAS Limited. Subsequently, it has been further developed and marketed by both Quadstone Limited and SIAS Limited (45, 48).

*Corridor Simulation (CORSIM)*. CORSIM is a computer traffic simulation model developed by FHWA. CORSIM represents the combination of two other computer models—Network Simulation (NETSIM) and Freeway Simulation (FRESIM). CORSIM, the most detailed urban computer simulation of the FHWA packages, simulates the traffic and traffic-control conditions of a network over a period of time. CORSIM can be used for a wide range of applications, including simulating HOV facilities. More detailed information on the capabilities and use of CORSIM can be found in its User's Manual (49).

*FREQ*. The FREQ model can be used for macroscopic modeling of HOV lanes, adjacent freeway lanes, and eligible vehicle ramp bypass facilities. FREQ simulates freeway sections by separating them into subsections and dividing the time period for the study into discrete time slices (8, 32, 50).

*FREFLO*. FREFLO is another method for the macroscopic modeling of freeway traffic operations, including traffic flow, density, and speed. FREFLO can be used for modeling general-purpose and HOV lanes (9). The model simulates the traffic conditions by representing the corridor as a series of sections in which vehicles try to enter. The number of vehicles that can flow to subsequent downstream sections in a given time frame is determined by the capacity of the section (9).

*Combined Modeling Approaches*. Many methods that combine demand and supply models have been developed by modelers to aid in estimating the mode choice impact of HOV facilities. The most common method to provide this estimation is by iterating the application of mode shift equations and level-of-service estimates. This approach is followed by most regionwide network models and by several models for monitoring corridor impacts (28, 54).

*CALINK*. The California Department of Transportation (Caltrans) combined the FREQ freeway simulation model with a regionwide traffic planning model (8). The resulting model, termed CALINK, utilizes an iterative procedure between the planning and simulation activities.

*Three-Tiered Screening Procedure*. A three-tiered methodology has been developed at the University of California at Berkeley to aid in determining candidate sites for HOV facilities (32). The process begins with a qualitative investigation of candidate sites in tier one and then proceeds into more quantitative methods in tiers two and three (9).

*Operational Analysis Tools*. Although there are several sources of motorist delay along arterial corridors, the largest delay is generally from signalized intersections. As a result, operational analyses of arterial HOV lane treatments usually focus on the delay experienced at signalized intersections along a corridor. The

following procedures can be used to estimate base-case delay, delay with signal priority projects, and delay with an HOV lane treatment to general-purpose vehicles.

It should be noted that in an urban arterial environment where right-of-way is limited, arterial HOV facilities might be justified even if there are impacts to the general-purpose traffic as long as these impacts do not unduly affect delay. It is important to evaluate the person-movement for HOV alternatives on arterial facilities when comparing alternatives and the impacts to the general-purpose traffic.

*Determining Base-Case Delay.* Base-case delay is the delay that can be expected in the design year without the benefit of an HOV lane treatment. Programs that analyze and quantify intersection delay such as Intersection Capacity Analysis Package (ICAP) are useful for such analysis. Examining delay by each movement is critical because an HOV lane treatment may be utilized to address a specific traffic movement through the corridor. For example, when considering a dual left-turn treatment, the left-turning delay is critical. The *HOV Systems Manual* provides further information (56).

*Determining Delay with Signal Priority.* Experience with the limited number of signal priority treatments in existence as of the writing of this document has indicated a reduction in delay experienced by transit vehicles of approximately one-third. As a result, the following equation has been used in some studies, in the absence of detailed analysis, to provide an estimate of delay for vehicles that are eligible for the signal priority (21, 56).

$$\text{Delay with Signal Priority} = (\text{Delay of Base Case}) \times 66\% \quad (1)$$

It is important to include only those transit vehicles that would be properly equipped and eligible for signal priority in this analysis because the results will be equated to the appropriate MOEs (e.g., cost effectiveness, person throughput) for the evaluation of alternatives.

*Determining Delay with HOV Lane Treatments.* HOV lanes and signal queue jump treatments provide significant travel-time savings to buses and HOVs. The travel-time savings in a queue jump lane will be partly dependent upon the amount of queuing in the HOV lane itself. The calculations for delay estimation for the treatments should consider the savings attainable by passing the queues at the signal.

For the HOV lane, the number of arriving vehicles is typically equal to the number of HOVs in the traffic stream. However, HOV lanes may be shared with general-purpose vehicles turning at signalized intersections. With this configuration, the arrival rate is equal to the sum of both the HOVs and the right-turning vehicles minus the vehicles that take advantage of the right-turn-on-red, if applicable (and only if a right-shoulder HOV lane is in operation), because they experience minimal delay. The lighter the HOV volume, the greater the likelihood that the right-turn-on-red can be utilized. Because center and left-side HOV lanes' turning movements are controlled by the signal operation, it is not necessary to consider these concerns for lane designations of this type.

The following equations may be used to estimate the arrival rate on an hourly basis considering the right-turn-on-red influence with a lane that is shared between HOVs and right-turning traffic.

If the HOV lane volume is less than or equal to 50 vehicles per hour, reduce the right-turn volume by 25 percent, yielding:

$$\text{Arrival Rate} = (\# \text{ of HOVs}) + [(\# \text{ of right-turning vehicles})(0.75)] \quad (2)$$

If the HOV lane volume is greater than 50 vehicles per hour, assume that no right-turn-on-red movements will be made, yielding:

$$\text{Arrival Rate} = (\# \text{ of HOVs}) + (\# \text{ of right-turning vehicles}) \quad (3)$$

*Combined Treatments.* Combining both treatments (such as implementing a signal priority treatment with a designated lane treatment) may be warranted in a corridor to provide a greater travel-time savings.

If combined treatments are being considered, the analysis can add the combined delay savings for vehicles that are eligible for both treatments.

*Delay Impacts of an HOV Lane Treatment to General-Purpose Vehicles.* Although total intersection delay is not necessary for the calculation of HOV delay, it should be investigated to ensure that the HOV lane treatment does not unduly affect the delay to general-purpose vehicles. It should be noted that in an urban arterial environment where right-of-way is limited, arterial HOV facilities might be justified even if there are impacts to the general-purpose traffic as long as these impacts do not unduly affect delay. The impacts on general-purpose traffic should then be compared among alternatives and the person-movement of the alternatives should be assessed.

### 1.2.2.3 Locating Freeway HOV Facilities

Experience in the United States has generally shown that urban freeways can be adapted to accommodate HOV lane facilities within existing freeway rights-of-way. The location of HOV lanes within the freeway right-of-way depends on the following:

- Existing freeway geometry;
- Required HOV lane cross section and alignment;
- Accessibility to the HOV lane and interchange spacing;
- Passenger modes at access points;
- Bus and other transit service characteristics;
- Adjacent land-use and environmental impacts;
- Cost of implementation; and
- Accessibility of supporting features (park-and-ride lots, transit, ramp metering, etc.).

The desirable length of an HOV lane facility within a freeway corridor can be estimated using a graphical technique such as that shown in Figure 1-2. This figure shows the distance for which speeds are below 50 km/h (30 mph) during a peak period. An HOV lane facility located within the freeway right-of-way for

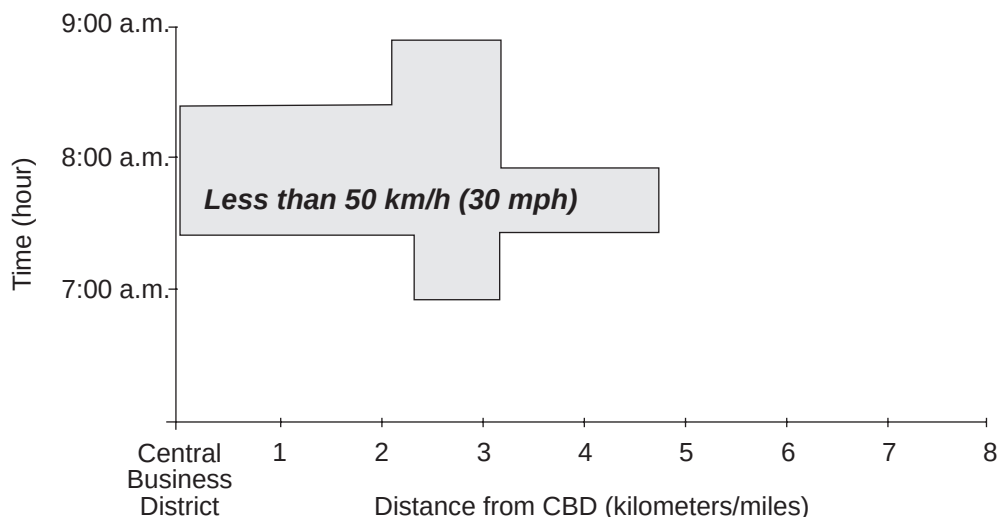


**FIGURE 1-2. Location and Duration of Congestion During the Peak Period (Adapted from Reference 3).**

the length of the congested area will allow eligible vehicles to bypass the congestion experienced on the general-purpose lanes and reduce travel time. The HOV lane facility should extend both upstream and downstream of the existing congested segment to allow for future congestion.

When a new HOV lane bypasses a congested area, speeds on the partially vacated general-purpose lanes may increase in the near-term, reducing the time savings. However, the HOV lane will not be effective if the additional capacity it creates reduces congestion entirely in the adjacent general-purpose lanes, thereby eliminating the incentive to carpool.

#### **1.2.2.4 Locating Arterial HOV Facilities**

The operating environment on arterial streets is much different from freeways. These differences relate primarily to the functions of the freeways and arterial streets. Freeways are intended to serve long-distance trips. As a result, freeways are designed to accommodate travel speeds of 90 to 110 km/h (55 to 70 mph). Freeways also have limited access points to help maintain a high volume of traffic.

Arterial streets, on the other hand, provide access to local streets and businesses. Arterial streets are designed to operate at travel speeds of 50 to 100 km/h (30 to 60 mph). Further, arterial streets have signalized intersections and often have driveway access for businesses and other land-use activities. The right lane on many arterial streets is often used for some combination of parking, delivery vehicles, bicycle use, and bus stops. The presence of pedestrian and bicycle modes also distinguishes arterials from freeways.

In addition, arterial streets are found within a wide range of settings and environments in an urban area. These include the downtown or central business district (CBD), suburban activity centers, neighborhood commercial areas or community centers, strip development corridors, adjacent schools or residential areas, and major commuter travel corridors. These areas all have different characteristics, which need to be considered in planning, designing, and operating arterial street HOV facilities.

All of these elements, which provide a much different environment than a freeway, must be considered in the development, operation, and enforcement of arterial street HOV facilities. The intent of HOV projects on arterial streets is similar to those on freeways—that is to provide travel-time savings and travel-time reliability to vanpools and carpools. As with freeway HOV facilities, it is also important to evaluate the person-movement for HOV alternatives on arterial facilities when comparing alternatives and the impacts to the general-purpose traffic. As indicated previously, in an urban arterial environment where right-of-way is limited, arterial HOV facilities might be justified even if there are impacts to the general-purpose traffic as long as these impacts do not unduly affect delay. Therefore, it is important to evaluate the person-movement for HOV alternatives on arterial facilities when comparing alternatives and the impacts to the general-purpose traffic. To accomplish these objectives, arterial street HOV facilities need to be coordinated and located with consideration of the other functions and elements of the roadway system. These include driveway access to businesses, schools, hospitals, and other land uses; signalized intersections; left and right turns for non-HOV traffic; on-street parking; delivery vehicles' destinations; avoiding conflict between HOVs and bicyclists and pedestrians; and buses stopping to drop off and pick up passengers.

Because arterial street HOV facilities may require changes in on-street parking, loading zones, and turn restrictions, a larger group of constituents often needs to be involved in the planning process, as well as developing the operation and enforcement plan. As noted previously, representatives from the major businesses, schools, neighborhoods, and other groups should be involved throughout all phases of planning, implementing, and operating an arterial street HOV facility.

#### **1.2.2.5 Determining the Appropriate Type of Freeway Facility**

At least four types of line-haul HOV facilities can be considered for implementation—an HOV facility in a separate right-of-way, barrier-separated facilities (including reversible and two-way facilities), concurrent flow lane(s), or contraflow lane(s). Chapter 2 further discusses these line-haul facilities and their operation.

Chapter 3 further describes the design of these facilities. Both chapters 2 and 3 also discuss HOV queue bypasses that may be used at ramp meters or toll plazas to provide HOVs a “head-of-the-line” advantage.

*HOV Facility in a Separate Right-of-Way.* This type of HOV facility is a roadway or lane(s) developed in a separate right-of-way and designated for exclusive use by HOVs. Most existing facilities of this type are designated for, and utilized by, buses only. Further, most are two-lane, two-direction facilities. Examples of this type of HOV treatment include the Martin Luther King Jr. (East), South, and Airport Busways in Pittsburgh; the University of Minnesota Busway in the Minneapolis/St. Paul metropolitan area; and the transitway system in Ottawa, Ontario. HOV facilities in a separate right-of-way are considered long-term solutions.

*Barrier-Separated Facilities on Freeways.* Barrier-separated facilities are usually located in the median of an urban freeway. They may be reversible or two-way, depending on anticipated demand and traffic characteristics. HOV lane facilities that are operated as reversible lanes usually are implemented on freeways that carry traffic with a high directional split during peak periods. A 60/40 split or higher in the design year and the absence of anticipated severe freeway congestion in the off-peak travel direction will usually justify consideration of a reversible facility. The evaluation of whether a two-direction HOV lane facility is needed should be based both on potential demand as well as on projected levels of congestion on the freeway lanes in the off-peak direction of travel. Barrier-separated facilities are more expensive than concurrent flow facilities to implement. Therefore, barrier-separated facilities are considered intermediate- to long-term solutions.

*Concurrent Flow Lanes on Freeways.* Concurrent flow HOV lanes are lanes in the same direction of travel that are not separated from the general-purpose traffic lanes. Paint striping is a common means used to separate these HOV lanes from general-purpose traffic. Concurrent flow HOV facilities can be either buffer- or nonseparated. Nonseparated lanes are suited for operations that revert back to general-purpose flow during certain hours of the day because they are often striped no differently than a general-purpose lane, while buffer-separated facilities are more applicable to 24-hour operation of the HOV lane. Nonseparated facilities generally allow for continuous and unlimited access while buffer-separated facilities provide access at select locations. This approach can be appropriate as an interim retrofit or long-term solution, with some projects adding shoulders and/or buffers to the lane cross section over time to increase operational safety. Accordingly, capital costs for concurrent flow lanes vary based on the desired cross section and extent of retrofit required.

The lack of physical separation and ease of access for users and nonusers increases the need for enforcement. Early involvement of the affected enforcement agency or agencies is essential for this approach. Access to the concurrent flow lane is another important consideration. Access can be allowed either continuously or at frequent intervals. Interval access can be achieved using skip striping for short entry points, typically at 1.6 to 3.2 km (1 to 2 mile) intervals. Access control is enhanced when using interval access as any crossing of the solid double line is a violation, regardless of occupancy. It should be noted that consideration of weaving between HOV and general-purpose traffic will need to be analyzed to ensure the operation of the facility, especially at the start, end, and intermediate access locations. Users may have difficulty merging across the general-purpose lanes to enter and exit the concurrent flow lanes. Travel-time reliability may also be lower due to the potential for incidents in the general-purpose lanes impacting the concurrent flow HOV lanes. These issues, along with others that relate to the operation and subsequent design, should be considered and are described more fully in the operations and design chapters for freeway facilities (see Section 2.1).

The lack of physical separation and ease of access also complicates efforts to implement pricing strategies. Design of electronic toll collection (ETC) systems will require limiting ingress/egress; without it, enforcement will be much more complex.

*Contraflow Lanes on Freeways.* If a strong directional split exists, at least 60/40, then a contraflow lane may be feasible. With this HOV lane treatment, one of the general-purpose lanes in the off-peak travel direction is dedicated for use by eligible vehicles traveling in the peak direction during peak periods.

Because contraflow lanes involve traffic operating in opposing directions on the same side of a freeway, safety for both HOV and general-purpose traffic should be a critical consideration in the design process.

Pylons or a moveable barrier can be used to provide lane separation. However, only trained drivers (buses and possibly vanpools) should use the contraflow lane when there is no rigid barrier separating it from the adjacent general-purpose lane. A contraflow HOV lane, which utilizes a lane in the off-peak direction, can be an appropriate intermediate solution. A critical issue associated with a contraflow lane is the growth in the off-peak direction of general-purpose traffic volumes during the operation of the contraflow HOV lane; if these volumes grow to a certain level, it is no longer feasible to “take a lane away” from opposing traffic for contraflow HOV lane use. It can also be difficult to provide intermediate ingress/egress for a lengthy contraflow lane. Furthermore, a contraflow lane requires relatively high day-to-day operating costs. Planning should consider whether a contraflow lane can operate long enough to justify its cost and whether adequate operating funds are available.

*General Timeframe and Costs for Different HOV Facilities.* Table 1-2 summarizes some of the planning considerations associated with HOV lane facility types.

### 1.2.2.6 Determining the Appropriate Type of Arterial HOV Facility

Numerous types of arterial HOV facilities and treatments provide a travel-time savings and travel-time reliability for HOVs on arterial streets. These facilities and treatments are discussed below. In most cases, arterial HOV facilities use existing lanes rather than adding new lanes. Many projects use the curb lane for a portion of the day, while a few projects have converted a general-purpose travel lane. Both of these conditions require special attention to the needs and safety of other user groups (e.g., reducing conflicts between bicyclists and transit unloading/loading). User groups may include motorists, delivery vehicles, bus riders, pedestrians, and bicyclists. Further, more information on the techniques below can be found in Chapter 4 of the *HOV Systems Manual* (56). The operations and design of these arterial HOV treatments are further discussed in chapters 4 and 5, respectively.

*Bus Malls.* Bus malls are bus or transit streets that are reserved exclusively for use by public transit vehicles. Most facilities provide access for emergency vehicles, however, and some allow taxis. Transit malls are usually found in downtown areas, although some are located in major suburban activity centers. Existing bus malls range in length from only a few blocks to major facilities covering many blocks. Many malls include passenger amenities, such as waiting areas, information kiosks, and other elements.

**TABLE 1-2. Typical Timeframe and Costs Associated with the Type of HOV Lane Facility (Adapted from Reference 3).**

| Type of HOV Lane Facility | Typical Timeframe |                   | Typical Costs   |            |             |
|---------------------------|-------------------|-------------------|-----------------|------------|-------------|
|                           | Implementation    | Life              | Capital         | Operations | Maintenance |
| Separate Right-of-Way     | Long              | Long              | Medium/High     | Low/Medium | Medium/High |
| Barrier-Separated         | Medium/Long       | Long              | Medium/High     | Low/Medium | Low/Medium  |
| Concurrent Flow           | Short/Medium      | Short/Medium/Long | Low/Medium/High | Low/Medium | Low/Medium  |
| Contraflow                | Short/Medium      | Short/Medium      | Low/Medium      | High       | Medium      |

*Right-Side Bus-Only and HOV Lanes.* This type of HOV facility uses the right-side lane on an arterial street for an HOV lane. Alternatively, the second lane from the curb may be used for HOVs. This approach is the most common application of HOV lanes on arterial streets. Right-side HOV lanes may be open to buses only, or buses, vanpools, and carpools may be allowed. Bus-only lanes are found in many downtown areas. These facilities commonly operate only during the morning and afternoon peak hours and help move buses through congested downtown areas. Bus-only or HOV facilities may operate in the curb lane or the second lane.

*Left-Side Bus-Only and HOV Lanes.* Left-side HOV lanes are a less common application of HOV lanes on arterial streets. Operating an HOV facility in the left lane of an arterial street eliminates the potential traffic conflicts related to curb lanes, such as on-street parking, delivery vehicles, bicycle traffic, and right-turn movement at driveways and intersections. These advantages may result in higher travel speeds and reduced stops and delays for HOVs. As a result, this approach may be appropriate for longer-distance HOV facilities. Potential issues with this technique include accommodating left turns for general traffic, as well as HOVs weaving across the general traffic lanes to make right turns. This treatment may also present significant problems to transit operations if buses must pull over to the curb to pick up and drop off passengers. An alternative is to provide passenger-waiting platforms adjacent to the left lane, which requires additional right-of-way and capital expenditures.

*Center Bus-Only and HOV Lanes.* This type of facility provides bus-only or HOV lanes in the center of an arterial street. A number of different treatments can be used with this approach, including a single reversible lane or lanes in both directions. Further, the lanes may be physically separated from the general-purpose lanes or paint striping can be used. Alternatives include two-directional center bus-only and HOV lanes or reversible center bus-only and HOV lanes.

*Contraflow Bus-Only or HOV Lanes on One-Way Arterial Streets.* This approach uses a lane on a one-way arterial street for buses only or HOVs operating in the opposite direction of travel. Currently, the only facilities of this type in North America are restricted to buses only and operate in downtown areas. Arterial street contraflow lanes can be an effective approach for moving high volumes of buses and HOVs through a congested area, such as a downtown or a major activity center. This technique, which is fairly common with light rail transit (LRT) systems, can provide benefits to transit operations by increasing the speeds of buses and enhancing travel time reliability.

*Spot HOV Treatments.* A number of treatments may be used to give buses or HOVs priority around a specific bottleneck or with special access to a facility. These techniques can provide HOVs with travel-time savings, enhanced travel-time reliability, and improved access to specific developments or activity centers. One treatment is a special access for buses only or HOVs only at a specific location. For example, a short arterial street or other treatment could be used to provide HOVs with direct or preferential access to a freeway entrance ramp, a park-and-ride facility, a major activity center, or a specific development. Allowing buses or HOVs only to turn left or right at designated intersections represents another spot treatment. A second possible approach would reserve one lane of a dual left- or right-turn lane for HOVs only.

*Signal Queue Priority.* Signal queue priority represents another set of techniques, which may be appropriate for consideration on arterial streets. Because traffic signals represent a major source of delay on arterial streets, time savings can be provided by allowing HOVs to bypass the queues at signals. These techniques include either signal queue jump lanes or bus advance areas (gating). The current uses of these approaches are directed primarily at public transit vehicles.

*Signal Priority Treatments.* Another approach is to provide priority treatment for buses and HOVs at signalized intersections. These approaches may be used in combination with other techniques or as stand-alone elements. A number of different techniques and technologies can be used to provide HOVs with priority at signalized intersections. Most approaches use some type of technology to communicate with the signal controller. Either extending the green phase or truncating the red phase then alters the timing of the signal cycle. These approaches involve modifying the signal algorithms. Signal priority approaches include the following, or a logical combination of the following: green-time extension, starting green phase early

or truncating the red phase, interrupting red phase or special phase, suppressing or skipping a phase, or window stretching. The *HOV Systems Manual* may be consulted for further information regarding these treatments (56).

**Bus Stop Treatments.** Many arterial street HOV applications are oriented toward enhancing the movement of buses through congested areas. The travel times of buses are influenced not only by the general-traffic conditions and signals along the roadway but also by the need to pull into bus stops, drop off and pick up passengers, and re-enter the traffic stream. These movements can add significant travel time to the overall operation of public transit vehicles.

The location and design of bus stops, bus bays or bus pull-in areas, bus bulbs, and other treatments can enhance transit operations and traffic flow along arterial streets. Many of these techniques can be used with or without HOV lanes. The report *Guidelines for the Location and Design of Bus Stops* provides a much more detailed discussion of elements to consider in the use of these approaches (55).

### 1.2.3 Facility-Level Planning

Planning at the facility level requires the greatest amount of detail. In general, facility-based planning is only initiated once a decision has been made to move forward with a selected alternative or alternatives. For example, if the recommended alternative from a corridor study is a concurrent flow HOV lane, the facility-based planning process would examine the specific elements associated with implementing this option. Specific issues related to access, design, enforcement, operation, and environment are considered with facility-level planning. It should be noted that the planning performed at the facility level should satisfy the elements, objectives, and policies of the regional plan outlined in Section 1.2.1 of this guide.

Planning at the facility level may focus on more pre-design planning elements, access treatments, demand projections at different vehicle-occupancy levels, the nature and location of bus services and park-and-ride lots, and other issues. A more detailed level of analysis is usually needed at this stage.

### 1.2.4 Sketch-Planning Techniques

Sketch planning represents a general or broad level of analysis. Sketch planning is most frequently used at a regional level or as a preliminary screen at the corridor and facility level. Sketch planning is intended to be a relatively simple process to help identify candidate areas, corridors, or facilities in need of transportation improvements, those where HOV facilities appear to be warranted, and the most logical type of HOV treatments. Sketch planning may be a precursor to the more detailed planning process described previously, or it may be a subpart of this process. For this reason, the models and techniques discussed previously may be used for sketch planning. The basic elements of sketch planning include the following:

- Identify criteria to be used in the screening process;
- Collect needed data;
- Conduct screening process; and
- Develop recommended plan or identify candidate treatments for more detailed analysis.

#### 1.2.4.1 Identify Criteria to Be Used in the Screening Process

The keys to defining effective criteria are:

1. Clearly defining the HOV project objectives to ensure the criteria are relevant to those objectives, and
2. Recognizing the limitations of the data-gathering capability, as readily available data from secondary sources are often used rather than comprehensive, original, field-generated information. The readily available data may have significant gaps.

The criteria used to determine whether an HOV lane is appropriate may include one or two elements or a series of factors. Some of the more common criteria, which are described in more detail in the *HOV Systems Manual (56)*, are as follows:

- **Congestion Levels.** The presence of severe and recurring congestion indicates that an HOV lane facility or other alternative may be appropriate. A level of service (LOS) D or E and recurring freeway average speeds of 50 km/h (30 mph) or less in the peak hour are common measures used in many metropolitan areas. The level of service should be examined along the facility and at intersections for arterial facilities.
- **Bottlenecks.** Specific bottlenecks or congestion points on an arterial street may cause significant delays. The existence of bottlenecks may point to the need for some type of priority treatment for buses and HOVs.
- **Level of Transit Service.** The level of transit service on a roadway can provide an indication of the need for an HOV lane facility. High volumes of buses may justify consideration of some type of priority treatment. Criteria may include the number of buses, as well as ridership levels.
- **Travel Patterns.** Examining the travel patterns, including the origins and destinations served by a potential HOV lane facility, is critical to determining the viability of different alternatives. At the sketch-planning level, this analysis usually focuses on travel producers, such as residential areas, and attractions, which include major employment and activity centers.
- **Current Bus and Carpool Volumes.** Existing transit services, carpools, and vanpools in a corridor can be used to provide an indication of the potential use of an HOV lane. Vehicle-occupancy counts and other available information on potential eligible vehicles in a corridor can be used during the sketch-planning process. A corridor with higher vehicle-occupancy levels may be a promising candidate for HOV lane treatments. Minimum person throughput and eligible vehicle volumes are both critical criteria for the success of an HOV lane. Person throughput is a good technical measure that can demonstrate that the HOV lane is actually carrying more people than a general-purpose lane. However, the public's perception of "success" of the HOV lane is much more dependent upon the number of vehicles using the lane.
- **Volume Operating Thresholds.** The goal of an HOV lane facility is to provide travel time-savings and travel-time reliability to eligible vehicles. Vehicle-occupancy requirements should be established at a level that will encourage use of the facility and the formation of new carpools without creating too much demand to make the lane congested. The number of vehicles using a lane on opening day and during the initial phases of a project should be high enough to justify the restricted use of the facility (i.e., since a general-purpose lane would carry more than 2,200 persons per hour in 2,000 vehicles at capacity, the HOV lane should carry at least that many people if it is to be a more efficient use of limited roadway capacity; for an HOV 2+ facility with primarily carpool use that translates into a minimum of approximately 1,000 vph). If the public perceives a facility to be underutilized, pressure may be exerted to reduce or eliminate entry requirements. The level of public perception may be specific to a region—those areas with mature HOV systems are likely to have higher thresholds than those where there is less congestion or where the HOV concept is just being introduced. The proportion of buses within the HOV lane traffic will also affect public acceptance.

The minimum threshold for a specific project will depend on the goals and objectives of the project, the type of facility, the vehicle-eligibility and vehicle-occupancy requirements, the level of congestion in the general-purpose lanes, and local conditions and perceptions. Table 1-3 presents illustrative minimum and maximum operating thresholds for different HOV lane facility types. The example minimum volume threshold for HOV lanes in the design year generally ranges from 700 to 1,000 vphpl on opening day. It should be noted that the minimum volumes are not “opening day” volumes, rather they are volumes to be satisfied in the design year of the facility. Bypass lanes range from 100 to 200 vphpl.

Minimum volumes for freeway contraflow facilities for trained drivers (e.g., buses, vanpools) range from 200 to 400 vphpl. Traffic volumes on HOV lanes should be monitored to help identify when maximum flow rates are being approached so that appropriate actions can be taken. As described above, Table 1-3 shows illustrative maximum flow rates. These flow rates generally range between 1,200 and 1,500 vphpl for different HOV lane facility types. Freeway contraflow facilities (trained-driver) range from 600 to 800 vphpl while bypass lanes range from 300 to 500 vphpl. These ranges are for illustrative purposes only and some areas have specified other maximum (or minimum) values. For example, Caltrans uses 1,650 vphpl as a maximum for concurrent flow facilities. Generally, as traffic volumes go beyond the specified maximum operating threshold, the HOV facility cannot sustain its travel-time reliability. The controlling factor for the capacity of an HOV lane facility is the facility terminus design and interchange locations. HOV lane facilities that exit into the general-purpose lanes and continue as their own lane will handle higher operating thresholds than facilities that require motorists to merge back into the general-purpose lanes. The design of interchange locations also affects the vehicle capacity of the facility. For example, interchanges at a T-ramp that require vehicles to appreciably slow down at the access location will not handle as many vehicles as T-ramp interchanges that are designed to include bypass lanes for nonexiting vehicles (18).

The capacity of high-occupancy toll (HOT) facilities will also be determined by the design of the facility. The ingress/egress and tolling stations can affect the capacity of the facility in the same way access locations will affect the capacity of HOV lanes. Consideration must be given to ensuring the vehicle mix allowed to the HOV lanes does not adversely affect the travel-time savings and/or travel-time reliability for eligible vehicles.

Table 1-4 provides example volume operating thresholds for arterial HOV lanes. Currently, little information is available on the vehicle volumes that an arterial street HOV lane can accommodate. As with freeway facilities, the goal of an HOV facility is to provide travel-time savings and travel-time reliability to buses, vanpools, and carpools. The vehicle-eligibility criteria and vehicle-occupancy requirement should

**TABLE 1-3. Example Volume Operating Thresholds for Freeway HOV Lanes**  
(Adapted from References 18, 56).

| Facility Type                                                             | Example Vehicle Volume Threshold <sup>1</sup> (vphpl) |             |
|---------------------------------------------------------------------------|-------------------------------------------------------|-------------|
|                                                                           | Minimum                                               | Maximum     |
| Freeway, barrier-separated two-way                                        | 700–1,000                                             | 1,200–1,600 |
| Freeway, barrier-separated reversible                                     | 700–1,000                                             | 1,200–1,600 |
| Freeway, concurrent flow                                                  | 700–1,000                                             | 1,200–1,600 |
| Freeway, contraflow, HOV lane                                             | 700–1,000                                             | 1,200–1,500 |
| Freeway, contraflow, trained drivers (e.g., buses, vanpools) <sup>2</sup> | 200–400                                               | 600–800     |
| Bypass lanes                                                              | 100–200                                               | 300–500     |

<sup>1</sup> The exact thresholds for a specific project will depend on the goals and objectives of the project, the type of facility, the vehicle-eligibility and vehicle-occupancy requirements, the level of congestion in the general-purpose lanes, and local conditions and perceptions.

<sup>2</sup> Contraflow facilities indicated with trained drivers are based on the absence of physical separation.

**TABLE 1-4. Illustrative Volume Operating Thresholds for Arterial HOV Lanes (Adapted from Reference 56).**

| Facility Type                         | Example Vehicle Volume Threshold <sup>1, 2</sup> (vphpl) |         |
|---------------------------------------|----------------------------------------------------------|---------|
|                                       | Minimum                                                  | Maximum |
| Bus Malls                             | 80                                                       | 400     |
| Right-Side Bus Only                   | 50                                                       | 200     |
| Right-Side HOV                        | 200                                                      | 800     |
| Left-Side Bus Only                    | 50                                                       | 200     |
| Left-Side HOV                         | 200                                                      | 800     |
| Center Two-Way                        | 200                                                      | 800     |
| Center Reversible                     | 80                                                       | 600     |
| Contraflow Bus Only on One-Way Street | 50                                                       | 200     |

<sup>1</sup> The exact thresholds for a specific project will depend on the goals and objectives of the project, the type of facility, the vehicle-eligibility and vehicle-occupancy requirements, the level of congestion in the general-purpose lanes, and local conditions and perceptions.

<sup>2</sup> The range of street capacity from densely spaced signals in a downtown environment to a high-speed limited access suburban arterial also make it difficult to be definitive on arterial HOV lane threshold vehicle volumes.

be established at a level that will encourage use of the facility but will not create too much demand and make the lane congested.

As indicated in Table 1-4, the exact thresholds for a specific project will depend on the goals and objectives of the project, the type of facility, the vehicle-eligibility and vehicle-occupancy requirements, the level of congestion in the general-purpose lanes, and local conditions and perceptions. For example, a facility carrying 40 buses per hour (i.e., less than that shown in Table 1-4) may be acceptable and beneficial based upon local conditions.

- **Vehicle-Eligibility and Vehicle-Occupancy Requirements.** Factors and threshold levels will vary by metropolitan area depending on local goals and objectives, facility types, design treatments, system connectivity, and local conditions. These elements can be used to help develop criteria for vehicle-eligibility and vehicle-occupancy requirements on HOV lane facilities. These elements include:
  - Metropolitan area and project goals and objectives;
  - Type of HOV lane facility;
  - Specific design or operating limitations;
  - Segment and area-wide continuity;
  - Existing vehicle-occupancy levels;
  - Travel-time savings and travel-time reliability;
  - Carpool and vanpool formation and increased transit ridership; and
  - Enforceability.

It should be noted that vehicle-eligibility requirements may be stipulated by funding sources. The web site [fhwa.dot.gov/operations/hovguide01.htm](http://fhwa.dot.gov/operations/hovguide01.htm) provides further information.

- **Travel-Time Savings and Travel-Time Reliability.** Estimating the potential travel-time savings and travel-time reliability offered by the HOV lane facility represents another sketch-planning criterion. A general guideline that is often used is that line-haul HOV lane facilities should provide an overall travel-time savings of at least five minutes before a mode shift starts to occur. Arterial treatments connected to freeway HOV lanes can contribute to an overall travel-time savings of eight or more minutes, which is desirable to effectively induce mode shift. Travel-time reliability is particularly important to high-frequency public transit operations; a reserved arterial lane for buses can sometimes be justified on improvements to schedule adherence reliability alone, no matter how little the average time savings.
- **Transit Delay.** In addition to the number of buses using a facility, consideration should be given to conditions delaying these vehicles. Traffic signals, turning vehicles, and general congestion levels may all influence the travel time and speed of buses operating on arterial streets. Identifying specific problems causing delays to buses is the first step in developing an approach to address these problems.
- **HOV Lane System Connectivity.** The success of an HOV lane may be further enhanced if it is part of a larger system of lanes. Consideration may be given during the screening process to those HOV lane elements that are critical parts of an overall network plan. Freeway-based HOV lanes may need an arterial street HOV lane to link to a major activity center. For example, eligible vehicles may experience significant delays accessing an exclusive freeway facility in a suburban area and exiting the facility into a downtown area. Providing arterial street HOV lane treatments may significantly increase the travel-time savings for eligible vehicles.
- **Roadway Improvements or New Developments.** Planned roadway improvements or the construction of new buildings and developments may provide opportunities for the consideration of HOV lane treatments. For example, in an arterial setting, an HOV lane or bus queue jump could be added as part of a road-widening project, or an eligible-vehicle-only entrance could be provided as part of a new development. Further, the implementation of a new traffic signal system may provide the opportunity to consider priority treatments for buses or HOVs.
- **Overall Trip Distance.** The average distance of commuter trips in a corridor can also provide a good indication of the possible candidates for HOV lanes. Longer distance trips may realize greater travel-time savings. Short HOV lane treatments can help address specific bottleneck problems and can be the basis for future extensions as an area grows.
- **Person Throughput.** HOV facilities should increase the person-moving capacity of a corridor or facility. An HOV lane should be designed to carry more people in fewer vehicles than the adjacent general-purpose lane, once lane demand has matured.
- **Projected Demand.** The number of buses, carpools, and vanpools projected to use an HOV lane represents another important criterion in the sketch-planning screening process. This is related to the example minimum and maximum volume operating thresholds previously presented. Chapter 5 of the *HOV Systems Manual* (56) outlines general guidelines and can be used in the sketch-planning process, as well as with more detailed analysis techniques. Pricing is one operational strategy that can be used to manage demand in the facility as HOV volumes grow over time.
- **Agency and Public Support.** Support from local, regional, and state agencies and the public is important to the success of HOV lanes and should be sought or confirmed during the sketch-planning process.
- **Financial Viability.** The cost of possible improvements and the availability of funding may be used to identify the financial viability of various options.

- **Enforcement.** Enforcement is a key component to the success of an HOV lane and must be considered in a sketch-planning process. The intended approach to enforcement and the related location, orientation, and general design of enforcement areas can be identified in the sketch-planning process.
- **Cost Effectiveness.** Cost effectiveness can be measured through a benefit-to-cost (B/C) ratio or similar approach. Benefits usually include reduced travel time and increased vehicle throughput, and reduced emissions (relative to a base case or “do-nothing” alternative) while costs generally include construction, operation, and maintenance of the facility. Additional considerations, such as air quality, fuel economy, and network-wide changes in vehicle miles of travel (VMT) may be included as well.
- **Physical Characteristics of the Corridor or Roadway.** Ensuring that an HOV facility can be physically accommodated in a corridor should be considered during sketch planning.
- **Support Facilities and Services.** Supporting services, such as park-and-ride lots, park-and-pool lots, transit services, rideshare programs, parking management strategies, and employer-based travel demand management programs are important to the success of an HOV lane facility.
- **Safety.** Examining potential safety issues, including design and operation, can also be considered during the screening process.
- **System Staging and Scheduling.** Sketch planning should consider the time needed to develop and implement an HOV lane, as well as how this schedule relates to other improvements. A major issue here is where the construction staging of a highway improvement may hamper the ability to implement an effective HOV project. For example, a long stretch of highway may be an ideal candidate for an HOV system, but if it is built in small pieces, disconnected from one another, and spread out over many years, the interim widenings will not be effective as standalone HOV projects and, hence, will be very difficult to preserve as HOV facilities.
- **Environmental Issues.** Assessing the possible benefits and issues at a preliminary level of detail can be used to help examine alternative approaches.
- **Other Modes.** The trip characteristics of the various markets should be examined to ensure that the alternatives are compatible rather than competitive. A thorough understanding of the entire shared-ride market and the potential for competition is needed to develop appropriate plans that support all shared-ride modes.

#### 1.2.4.2 Collect Needed Data

The next step in the sketch-planning process is to collect the data needed to analyze the screening criteria. Sketch planning usually relies on available information and does not require additional data-collection activities. The following existing information sources may be appropriate for use in a sketch-planning process:

- **Traffic Data.** State DOTs, MPOs, transit agencies, cities, and other groups conduct ongoing data-collection activities related to many aspects of the transportation system. Information on traffic volumes, vehicle-occupancy levels, crashes, and origins and destinations may be available from existing sources.
- **Transit Data.** Information on existing bus routes, park-and-ride lots, and ridership levels is usually available from the transit agency or operator. Transit operators should be consulted to understand how they might change routes/services to take advantage of an HOV facility. This information can be used to establish a baseline level of transit service in the corridor or on a specific facility.

- **Rideshare Data.** Information on existing carpools and vanpools may be available from the transit or rideshare agency. This information may help establish a baseline for rideshare activities at the regional, corridor, or facility level.
- **Census Data.** Census data on the number of households and residents in an area, income levels, automobile ownership, and travel characteristics may be of use in the sketch-planning process.
- **Aerial Photographs.** Aerial photographs may be used in identifying right-of-way constraints and opportunities.
- **Land-Use Maps.** Land-use maps can be used to provide an indication of both existing and future land-use patterns and densities in an area or a corridor. Employment density and the location of major trip generators should be highlighted.
- **Bicycle Master Plans.** If an arterial is a primary bicycle route, this could influence the evaluation of the arterial for an HOV facility.
- **Geographic Information System (GIS).** Geographic information systems may provide transportation, land use, and other data useful to sketch-planning exercises.

A decision will need to be made as to whether the readily available data provide an adequate basis for completing the screening process or if new data need to be collected in the field.

#### 1.2.4.3 Conduct Screening Process

In this step, the alternatives are evaluated based on the selected screening criteria. The screening process may be kept relatively simple, or a weighted evaluation process or other technique may be used. For example, at a basic level, the criteria could either be met or not met. A more complex approach may involve weighting the criteria or applying a “fatal flaw” analysis that would eliminate an alternative from further consideration. The alternatives emerging from fatal flaw analysis are then carried through a more detailed sketch-planning process or into a second-phase analysis. If Federal funds are anticipated to be used for a project, the “no build” alternative is required for the National Environmental Policy Act (NEPA) process. The no build alternative is also often useful in providing an assessment of the public investment when compared to the “build” alternatives.

#### 1.2.4.4 Develop Recommended Plan or Identify Candidate Treatments for More Detailed Analysis

The results of the sketch-planning process may be a preliminary regional, corridor, or facility plan or the identification of HOV treatments or other improvements for more detailed analysis. Sketch planning is often the first step of a comprehensive process, with the results used as input to more detailed corridor or facility planning.

### 1.3 ADDITIONAL PLANNING CONSIDERATIONS

The planning approaches described previously are appropriate for use with all types of HOV lanes. However, some projects may require special considerations during the planning process. This section discusses additional factors that may need to be examined for special situations.

#### 1.3.1 Link Between Design, Operation, and Enforcement

For both freeway and arterial HOV lanes, there is a need to consider design, operation, and enforcement needs in the planning stages. Many of these elements would likely be considered at the corridor, facility,

and/or sketch-planning levels. For example, at a strategic meeting for a particular project, many of the project-specific concerns that relate to the design, operation, and enforcement of the facility could be discussed. It is at the planning level that initial design decisions are made and the relationship of the design to the eventual operation and enforcement of the facility should be considered. Different operational strategies will affect the design of the facility. These design and operation issues are further discussed in later chapters of this guide, but consideration for them should first begin in the planning stages. More specifically, further discussion of the link between design, operation, and enforcement can be found in Section 2.1 for freeway HOV facilities. For example, for freeway facilities, further operational considerations include the need for traffic management and surveillance and the ability to detect incidents and dispatch response vehicles.

The design, operation, and enforcement of the facility should also be consistent with the regional plan (see Section 1.2.1) and the agencies that are within the jurisdictions of the regional plan. This would ensure that planning for the HOV lanes follows the regional concept of HOV operations and design. The interrelationship of HOV lane operation, design, and enforcement and how planning must consider these elements is shown visually in Figure 1-3.

### 1.3.2 Planning for New HOV Lanes Prior to Full Utilization

Planning for major transportation improvements typically takes many years to complete prior to actual implementation. HOV lanes should not be implemented until appropriate levels of HOV demand can be achieved. However, it is important when planning for HOV lanes that the traffic growth projections indicate that HOV demand will be reached within a few years of implementation and not when the facility opens.

The interim period can be handled in several ways. In all cases, the facility should be clearly signed and striped from its inception as an HOV lane. One approach for interim use is to allow other non-HOV user groups to access the facility. An extensive public information campaign must be conducted to educate users that the current permitted use is temporary, and multijurisdictional concurrence of temporary use is critical. The following are possible methods to increase ridership during the interim period of an HOV lane.

- Inherently low-emission vehicles (ILEVs) may be permitted to use the facility. This requires a separate sticker program to identify qualifying vehicles and associated enforcement resources. As before, objectives should be clearly defined for the facility, and multijurisdictional support will be needed at the policy level.
- Certain single-occupant vehicles (SOVs) could be permitted to use the facility on a rotating basis.

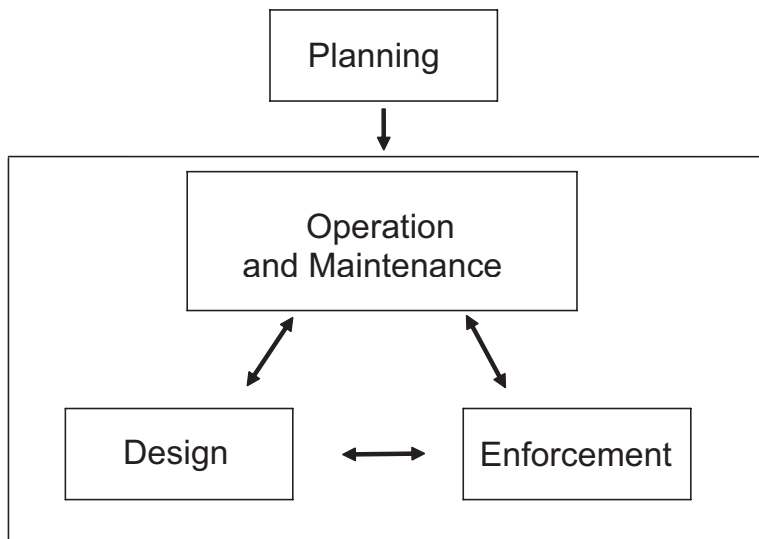


**FIGURE 1-3. Interrelationship of HOV Lane Considerations.**

- SOVs could also be allowed unlimited temporary access to the facility. The new lanes should never be considered “general purpose,” but instead the information campaign should clearly portray the lanes as HOV lanes that are currently allowing access by SOVs. This approach should be considered carefully to ensure HOV facility success.

It should be noted that implementing some of these alternatives may be limited as vehicle-eligibility requirements may be stipulated by funding sources. Further information can be found at [fhwa.dot.gov/operations/hovguide01.htm](http://fhwa.dot.gov/operations/hovguide01.htm).

Typically, national experience has shown strong resistance to conversion of a general-purpose lane to an HOV lane. Many potential HOV lane projects have projections of eligible vehicle volumes that will exceed the locally accepted “minimum” HOV demand, but those volumes are not anticipated until a few years after the opening of the facility. As a good planning practice, HOV lane facilities should be developed with future volumes in mind. A few projects nationally have succeeded in opening lanes to general traffic for some period of time, until eligible vehicle volumes warrant such restrictions. From a public perception perspective, this approach can be risky and should be carefully considered. One effective strategy has been to demonstrate clearly to the public that the new lanes are HOV lanes, but general traffic is being allowed to use the HOV lanes only as a temporary condition. This may be accomplished by clearly signing and striping the facility as an HOV lane showing temporary access to general traffic. Also, it is important to initiate a public information campaign explaining all of the steps in the process with an anticipated schedule of when the lane will revert back to HOV use only. This approach is not likely to work if general-purpose traffic is allowed to use the lane for several years.

### 1.3.3 Planning for Priority Pricing and Incentive Programs on HOV Lanes

Priority pricing, also referred to as value, variable, or congestion pricing, provides motorists with alternatives when traveling in congested periods. This can be in the form of paying to use a premium service, such as utilizing excess capacity on an underutilized HOV lane, paying a reduced toll on a tolled facility to stay out of the peak traffic period, or paying to utilize an uncongested express lane. The intent is to offer an alternative to traveling in congestion and using price as a means of regulating demand.

Related approaches include priority pricing, value pricing, or HOT lanes. These approaches use pricing strategies on HOV lanes. Examples of this technique include charging 2-person carpools to use the lane but allowing 3+ carpools to use the facility for free, or charging single-occupant vehicles a fee but allowing 2-person carpools to travel for free. Advanced technologies, including automatic vehicle identification (AVI) and electronic toll collection (ETC), provide the opportunity to implement variable pricing techniques easily and with minimal delay to users. The inability to prevent vehicles weaving across a dashed line or painted buffer presents a major challenge to HOT lane implementation beyond the barrier-separated environment. The ability to implement priced HOV lanes, or HOT lanes, without physical (barrier or pylon) separation has not been demonstrated at the time this document was written.

HOV lanes may evolve as demand grows. When most HOV lanes open with an HOV 2+ eligibility designation, excess capacity is experienced. Some HOV 2+ lanes will exceed capacity for the HOV 2+ designation due to a growth in HOV 2+ traffic. Over time, for the more successful HOV lanes, growth in HOV traffic may overwhelm the facility, reaching what can be termed the “critical operating threshold,” which is the traffic volume beyond which free-flow conditions begin to degrade (53). Authorities managing these facilities must decide whether to endure congestion in the HOV lane, add more lanes, or change to an HOV 3+ designation during part or all of the operating period. Figure 1-4 illustrates how an HOV lane with a “buy-in” provision at various stages in the HOV lane’s development can help to more fully utilize a facility’s capacity, without jeopardizing transit operations.

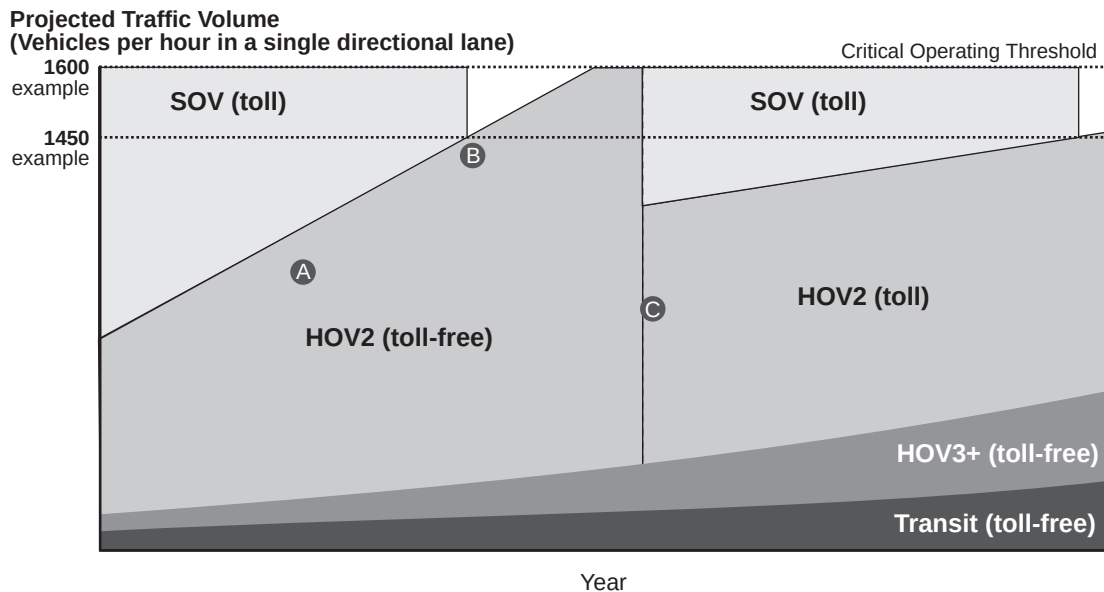


**FIGURE 1-4. Example Lifespan of HOV Lanes (Adapted from References 52, 53).**

### 1.3.3.1 Pricing as a Consideration in HOV Project Financing

Current HOV projects involving a toll component use pricing primarily as a demand management tool as opposed to a financing tool. However, the transportation financing mechanisms available today reflect a shift from the traditional means of grant-based funding to address the realities of certain funding shortfalls. Federal and state governments, as well as state DOTs, are working collaboratively with other local entities and the private sector to maximize the effectiveness of every transportation improvement. The fact that a project has a dedicated revenue stream makes it a more likely candidate for nontraditional funding. Additionally, these projects may attract private-sector investment. HOV lanes that incorporate pricing strategies can be the type of innovation that strives to balance the fiscal constraints of building and operating new infrastructure and the public policies that seek to promote bus transit use and ridesharing.

Pricing and other innovative financing strategies can be used to accelerate HOV-related projects and/or make them financially feasible. The strategies may be used alone or in tandem to greatly enhance the financial viability of a project. Often these projects are significant undertakings that require leveraging monies from every available source. Every effort should be made to include any and all interested parties from the earliest stages of project financial planning. Not only does this foster a collaborative attitude, but it may help identify potential financing sources and investment opportunities. The key to developing a successful project is to identify the project goals and match the financing to the purpose (16).

### 1.3.3.2 Projects and Incentive Program Examples

The example shown in Figure 1-4 is described in detail elsewhere (52, 53). In addition, References 44 and 53 include a discussion of the following pricing projects:

- SR 91 Express Lanes, Orange County, California;

- I-15 Express Lanes, San Diego, California; and
- I-10 (Katy Freeway) and US 290 (Northwest Freeway) *Quickride*, Houston, Texas.

### 1.3.3.3 Pricing Project Implementation Issues

Based on the limited experience with pricing projects, it appears a number of issues should be examined when considering pricing strategies on new or existing HOV lanes. These issues are described below.

*Project Objectives.* Pricing may be considered for a number of reasons. Determining the specific goals and objectives of a project is a critical first step. Possible objectives for a pricing project include improving HOV lane utilization or maximizing available capacity by allowing lower-occupancy vehicles, restoring free flow to HOV lanes by charging lower-occupancy vehicles, generating additional revenues, introducing another travel option, and supporting other secondary impacts such as air quality.

*Pricing Alternatives.* Examining the amount the target market may be willing to pay to use an HOV lane should also be considered. A number of factors may be considered in this assessment, including the estimated demand at various pricing levels and quality of service. In addition to the traditional cost-to-demand relationship, other factors to consider include the bus fares in the corridor and the cost of other transit alternatives.

*Impact on Existing or Projected HOV Lane Users.* There should be no impact on HOV lane users, who are to be favored. Specifically, the travel-time reliability for existing HOV lane users should not be negatively impacted by the addition of priced users. For instance, on an existing HOV lane, buses and permitted HOVs should always maintain the travel-time advantage of using the lanes. This has been successfully accomplished on I-15 in San Diego through the use of dynamic pricing, which monitors the usage of the facility on a continuous basis (as frequently as every six minutes).

A number of negative impacts might result from pricing, however. For example, increased congestion in the HOV lane might occur if tolls are set too low, resulting in too many lower- or single-occupant vehicles using the facility. This situation could result in slower travel speeds, reduced travel-time savings, and decreased travel-time reliability. Person volumes may decline if existing bus riders, carpoolers, and vanpoolers decide to change to driving alone for a fee. Favorable results may occur if revenues generated from pricing are used to enhance bus service in the corridor, to reduce bus fares, to subsidize vanpool fares, make improvements to bicycle transportation facilities, or to make other improvements benefiting HOV lanes.

*Level and Use of Revenues.* The level of revenues generated and the projected use of the revenues should also be considered. The focus groups conducted during the planning process for the I-10 (Katy Freeway) demonstration in Houston, as well as findings from other congestion pricing studies around the country, indicate that public support appears to be higher if the revenues are used for transit and transportation improvements than if they are used for other purposes. The revenues for the I-15 project in San Diego are funding additional transit services in the corridor. Some oppose the concept of pricing, since freeways and roadways have already been paid for through tax dollars. In addition, equity issues have been raised, related to the perception that only the wealthy will be able to afford to use the lanes. Survey data from the SR 91 express lanes show that these concerns can be addressed as there is a wide range of incomes of the users of the facility (51).

*Public and Political Acceptance.* Public involvement has become an important step in the project planning process. However, when considering an HOV lane project that involves pricing, public involvement should go one step further and include a more comprehensive public education component. In this regard, public education differs from public involvement in that people are unfamiliar with the pricing concept as it applies to transportation. It should be thoroughly communicated and include all aspects of the project, such as goals, objectives, operations, and revenue use. While the public is familiar with some examples of pricing to manage demand of goods and services, many do not understand this concept when applied to transportation. Research has shown that in focus groups, individuals are more supportive of the concept after they are

shown examples of successful HOT lane projects and how they operate (15). Identifying a project champion is also crucial to the success of an HOV lane project utilizing pricing. Research has found that successfully implemented projects have had a strong advocate (15). This person can be used as a spokesperson in the education process.

*Operational Strategies.* The two general types of operational approaches are a manual or static technique and an automated technique using AVI or toll tags. Consideration should first be given to comparing manual and automated techniques. The payment method is the first consideration. In most cases, a motorist will pay a specific amount for a manual tag regardless of how often they use the facility. The automated method allows individuals to pay on a per-trip basis. Manual approaches can be implemented for lower costs; however, they may be more difficult to enforce.

### 1.3.4 General Design and Cost Factors

Design and cost factors are often important elements in the planning process for HOV facilities. The availability of needed right-of-way and the cost associated with different alternatives are often screening criteria or evaluation measures. Additional design factors may be considered during the planning process to ensure that the selected options are viable. The capital and operating costs associated with various types of HOV lane facilities will vary greatly depending upon right-of-way and the purchase price of needed land; contracting procedures; soil, wetlands, and other environmental issues; weather factors influencing the construction season; and special considerations such as the need for seismic considerations. Costs will also vary based upon the level of intelligent transportation systems (ITS) provided on the facility, including electronic equipment, communication lines and wiring, detectors, and surveillance (e.g., inductance loops, cameras), or dynamic message signs (DMS). The number and type of ingress/egress locations can also affect costs. The information below provides a general indication of the costs associated with various approaches that may be used as general parameters in other areas.

The recently completed one-lane reversible section of South R.L. Thornton (I-35E) in Dallas, Texas, ranged from \$3.1 to \$4.3 million per kilometer (\$5 to \$7 million per mile). One concurrent flow lane in each direction ranges from \$1.9 to \$3.1 million per kilometer (\$3 million to \$5 million per mile) based on California and Virginia experiences. Costs of HOV facilities are highly variable and higher in locations where adding a lane requires major bridge and retaining wall construction (e.g., Seattle). To date, the construction cost ranges from \$70 to \$150 million for an individual bi-directional freeway-to-freeway HOV direct access ramp. In southern California, cost estimates for individual bidirectional direct connectors range from approximately \$100 to \$200 million including right-of-way. As shown by this information, there are relatively large ranges in the costs of different facilities.

The difference between “real” and “incremental” HOV lane cost is worth noting. In most HOV lane cases, the freeway is congested and transportation agencies need to widen the facility for general-purpose traffic lanes anyway. It may be argued that for concurrent flow HOV facilities, the addition of the HOV lane is only for some signage, buffer-separation, and enforcement provisions. Therefore, the “incremental” cost of the HOV facility is only a fraction of the “real” cost of the entire freeway widening.

#### 1.3.4.1 Cost Effectiveness for Freeway and Arterial Facilities

Cost effectiveness is usually determined by comparing the capital costs associated with an HOV lane project with the anticipated benefits along the corridor. The benefits may include quantifying the travel-time savings of buses and other eligible vehicles and operational savings realized by public transit operators. The time savings to eligible vehicles may be based upon a generalized or local cost per hour of day.

Costs of arterial HOV lanes can be determined by evaluating the capital costs of converting or adding lanes. If the arterial HOV lane is being converted from an existing lane, then the costs would likely consist of striping, signing, and possibly adding a buffer, while a new arterial HOV lane is typically evaluated as any other widening project. Additional costs, such as the delay to motorists in adjacent general-purpose

lanes, are more difficult to measure and are typically ignored. Decisions are generally based on the capital costs, the anticipated benefits to eligible vehicles and transit, and the policy to promote higher occupancies. For more information on arterial HOV lane costs and benefits, please refer to the 1994 report, *Operational Design Guidelines for HOV Lanes on Arterial Roadways* (33).

Quantifying these benefits may not be an easy process. The value of a traveler's time will depend on the type of trip and the local economic environment. Estimating potential benefits to transit operations may be easier, as the savings in travel time and potential to reduce vehicle needs can be estimated. Tables 1-5 and 1-6 provide more information on benefit-cost analysis (59). As indicated at the end of Section 1.3.4, consideration of the capital cost being compared against is important to define (i.e., the "incremental" extra cost of adding the HOV facility or assigning the entire widening cost to the HOV project).

### 1.3.5 Transit Planning for HOV Lane Facilities

HOV lanes often incorporate bus services and bus facilities. Transit agencies have the overall responsibility for planning, financing, implementing, marketing, and operating bus services associated with HOV lane

**TABLE 1-5. Possible Benefit Components for a Benefit-Cost Analysis**  
(Adapted from Reference 59).

| Component                          | Value   | Comments                                                                                                                                                                |
|------------------------------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Reduced Delay                      | \$/Hour | Any reduction in total freeway delay (travel time) can be converted to benefit by applying a dollar value to a person's time.                                           |
| Reduced Fuel Consumption           | \$/Trip | Gasoline saved per person trip because of mode shift is a benefit. A by-product of reduced fuel consumption is the reduction of pollutants emitted into the atmosphere. |
| Reduced Bus Operating Cost Savings | \$/Hour | Higher speeds on the HOV lane facility will mean that fewer bus hours are needed to provide the required service.                                                       |

**TABLE 1-6. Possible Cost Components for a Benefit-Cost Analysis**  
(Adapted from Reference 59).

| Component            | Value   | Comments                                                                                                                                                                                                                       |
|----------------------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Initial Capital      | \$/Year | This should include the cost for planning, designing, and constructing the HOV lane facility. The costs should be annualized as a function of the projected lifetime of the facility.                                          |
| Day-to-Day Operation | \$/Year | Depending on the type of an HOV lane facility, this should include costs for reversing one-way operation, set up and removal of pylons and/or barriers, incident response, central control center personnel, enforcement, etc. |
| Bus Operation        | \$/Year | Implementation of an HOV lane facility will generally increase the number of buses needed on a day-to-day basis. This additional cost should be considered.                                                                    |
| Maintenance          | \$/Year | Any additional maintenance cost for an HOV lane facility, especially a separated roadway, should be included in the analysis.                                                                                                  |