MODULE 6. HOV TREATMENTS

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Figure 6-1. HOV Lane in San Diego, CA.

6.1 INTRODUCTION

Preferential treatments for high occupancy vehicles (HOV) have proven to be one of the most flexible, cost effective alternatives for increasing the person-moving capacity of congested metropolitan transportation systems. The concept emphasizes *person movement* rather than traditional *vehicle movement*. It offers multi-person vehicles the opportunity to travel in reserved lanes that allow higher operating speeds and more reliable travel times. HOV treatments are not appropriate in every situation, but their applications are growing as more and more metropolitan areas face the challenge of improving mobility, particularly during peak travel periods.

Constraints on metropolitan mobility have been identified as among the most serious transportation issues affecting the economic and social vitality of the nation. Many regions of the country, recognizing this critical importance of continued mobility, have established the following areawide goals:

- Reduce vehicle-miles of travel.
- Conserve energy.
- Reduce air pollution.

HOV facilities can be a major component in regional efforts to improve the operational efficiency of a freeway by:

- Increasing the people-moving capacity of the facility.
- Offering high-speed travel to a larger number of people (to decrease the average travel time and make it more predictable).

- Providing an incentive for people to share rides (to increase the number of persons carried per vehicle).

The objective of HOV lanes is, of course, to move more people in fewer vehicles than conventional highway lanes. A dramatic example of the person-moving capability of an HOV lane is on 4 km (2.5 mi.) of I-495 in New Jersey, between the New Jersey Turnpike and the Lincoln Tunnel entering New York City. Here a contraflow lane, a lane in the off-peak direction, separated from the adjacent lane with plastic posts during the morning peak, carries 35,000 people in 750 buses during the peak hour, and more than 70,000 people in 1650 buses in the 3-hour peak period. It would require 15 conventional freeway lanes to move the same number of people in the peak hour. Certainly, no other city has the employment density or transit use of the New York/New Jersey Metro area, but HOV facilities throughout the country are accomplishing the same objective by providing a reduced travel time and travel time reliability incentive for drivers to change mode to HOV. Existing freeway HOV lanes carry the person-equivalent of two to five conventional lanes, and do so at a higher level of service than the conventional lanes. If an HOV lane becomes congested, the occupancy requirement can be raised, or other adjustments can be made to accommodate additional vehicles and thus additional people.(1)

TREATMENTS

Priority treatments may be either dedicated mainline lanes or isolated improvements that bypass a bottleneck. These treatments include the following:

- Exclusive HOV Facility - Separate Right-of-Way.
- Exclusive HOV Facility - Freeway Right-of-Way.
- Concurrent Flow Lane.
- Contraflow Lane.
- Queue Bypass HOV Facility.

These treatments are best served when implemented with a number of other transportation demand management measures to encourage use such as:

- Rideshare matching services.
- Guaranteed ride home.
- Employer incentives through preferential parking.
- Parking cost incentives.
- Supporting facilities that help to collect and distribute passengers.
- Public information.
- Education programs.

MODULE OBJECTIVES

The objectives of this module are to accomplish the following:

- Present the process for developing HOV treatments within a freeway system.
- Provide a summary and description of different HOV treatments in use, including both HOV lanes and supporting facilities such as park-and-ride and preferential parking programs.

- Discuss planning, design, construction, operating, and maintenance issues associated with the different HOV treatments.

MODULE SCOPE

In view of the impressive HOV success stories of Houston, Seattle, and other cities (see **section 6.5**), a high interest exists in implementing HOV treatments within freeway systems. This module presents the basics for HOV treatments associated with freeways. Treatments on arterial roadways can also support the freeway system, however those treatments are not discussed here. Information on the different freeway treatments and their supporting parking-related facilities are presented along with discussion on issues associated with those facilities. An emphasis of this module is on the need for cooperation between the partners and the presentation of issues that need to be considered during the planning process.

6.2 DESIGN PROCESS

IDENTIFY PROBLEMS/NEEDS

High Occupancy Vehicle facilities are viable components of freeway systems. The needs that can be addressed by HOV facilities include the following:

- Increasing person-carrying capacity of a highway corridor.
- Reducing total travel time.
- Reducing or defer the need to increase highway vehicle-carrying capacity.
- Improving efficiency and economy of public transit operations.
- Reducing fuel consumption.
- Improving air quality.
- Inducing mode shift.

Factors that influence consideration of HOV facilities include:

- Congestion.
- Travel time savings.
- Person throughput.
- Vehicle throughput.
- Local agency support.
- Enforceability.
- Physical roadway characteristics.
- Support facilities.
- Environmental mitigation.
- Compatibility with other modes.

The two criteria that most commonly appear to influence HOV viability are *congestion* and *travel time savings*. Without existing or forecasted congestion, the HOV alternative offers no substantial benefits for single-occupant drivers to switch to carpool, vanpool, or bus. Although the definition of "congestion" varies from one locale to another, a good measure of congestion is average freeway speeds of 48 km/h (30 mi/h) or less during the peak hour, or 56 km/h (35 mi/h) or less during the peak period. In some instances, an HOV alternative has been considered for a congested freeway that could operate relatively smoothly with an added mixed-flow lane, but for which future congestion is predicted. Travel time savings has become one of the most reliable predictors of HOV viability, and it must potentially exist to encourage mode shifts. For most treatments, a projected 5-minute or more savings per trip is generally recognized as a prerequisite. Time savings of less than 5 minutes may still justify consideration of queue bypass where a modest investment benefits many drivers.[3]

An assessment of HOV projects in six U.S. cities—Houston, Minneapolis-St. Paul, Pittsburgh, Seattle, Washington, DC, and Orange County, California—found the following common elements in the decision-making process: [4]

- *Corridor and areawide characteristics*. An awareness of the need to address increasing traffic congestion problems in the corridor had developed.
- *Lack of a fixed-guide way transit plan for the corridor*. No decision had been made on the development of a fixed-guide way transit system in the corridor where the HOV facility was ultimately developed.
- *Planned or scheduled highway improvements*. HOV projects were considered and implemented as part of an extensive program of highway improvements. This coordination helped maximize available resources and minimize impacts on implementation.
- *Project champion or champions*. Individuals in positions of authority in highway and transit agencies supported the HOV concept and promoted it throughout the project development process.
- *Legislative direction and policy support*. Legislative or agency policies and directives played an important role in the decision-making process in some HOV projects.

To assist with defining the problems that exist within the freeway system so that appropriate decisions can be made, an inventory of physical and organizational components is needed. Table 6-1 lists some of the specific types of information needed.

IDENTIFICATION OF PARTNERS

The key partners in the development of an HOV facility component of a freeway management system include the following:

- State Department of Transportation.
- Transit Authority (or Authorities).
- Federal Highway Administration.
- Metropolitan Planning Organizations.
- Enforcement Agencies.
- County or City Departments of Transportation.

In addition, the following can be key in developing a successful plan, rather than one that is challenged during the development and/or construction of a facility:

- Elected Officials.
- Media representatives.
- Citizens.
- Representatives from private businesses.
  - Major traffic generators.
  - Businesses with ride-sharing programs.

Table 6-1. Information Needs for Successful HOV Operations.

- Person-Moving Capacity of the Roadway Facility
- Potential for Support Facilities Such as Park-and-Ride Lots
- Origins and Destinations
    - Activity Centers
    - Point of Origin
    - Average Trip Length
    - Trip Times
- Traffic Operation on Freeway Mainlane
    - Average Delay
    - Peak Period Volumes
    - Average Travel Speeds
    - Travel Time
- Bottlenecks
    - Location
    - Duration
    - Causes
- Vehicle Occupancy
    - Percentage of Peak Period 2+ and 3+ Vehicles in the Traffic Stream
- Future Demand
    - Growth Factor of Corridor
    - Growth Factor of Parallel Routes
- Transit and Rideshare Patronage
    - Types of Operations That Could Benefit from HOV
    - Existing and Planned Transit Services
- General Design Limitations of Existing Freeway Facility
- Safety and Accident Data
- Violation and Enforcement Data
- Information on the Perception of Users, Non-Users, and the General Public

In some cases, for example the development of a park-and-ride facility has included other non-traditional partners. Other important partners that can be involved in the decision-making process include the following:

- Owners/operators of major traffic generators.
- Churches whose parking lots could be used for weekday commuters.

Successful HOV systems requires good coordination between respective governmental agencies. Two examples of areas where effective coordination has occurred include Houston and Seattle.[5] Agencies primarily involved in the implementation of HOV facilities in Houston included:

- Texas Department of Transportation.
- Metropolitan Transit Authority.
- Federal Highway Administration.

Agencies involved in Seattle included:

- Washington State Department of Transportation.

- Puget Sound Council of Governments.
- Seattle Metro Transit.
- Pierce County Transit.
- Municipality of Metropolitan Seattle (Metro).
- King, Pierce, and Snohomish Counties.
- City of Bellevue.
- Federal Highway Administration.

Additional information on the Houston and Seattle systems is provided later in this module.

CONSENSUS BUILDING

Having an overall consensus and developing good working relationships within and between agencies are important in implementing an HOV facility system. During initial meetings, identifying and understanding the differences in operational philosophies and priorities of the different partners will assist in the process. For example, major business associations may be more concerned with the location of ramps to and from an HOV lane, and whether those ramps will go into a parking garage, while a transit agency's priority may be to have the ramps exit to a downtown street.

The importance of public support needs to be recognized early in the process. Extensive public relations and media campaigns may be needed to show the public the benefits of the HOV facilities. An important lesson that has been learned from project failures to date is that the public must be involved and must be able to understand and appreciate the role that HOV systems can serve. Public participation will need to be focused and pursued at various levels.

A multi-agency review group (also called an advisory committee or steering committee) should be formed. Their role includes technical and policy guidance, concurrence powers at major decision points, coordination and liaison with others in the respective agencies, and outreach to greater public participation efforts as needed. Apart from the multiagency review group, focus groups composed of local civic associations, special interest groups, politicians, the media, and others may be necessary to link public participation with the process.[5]

ESTABLISH GOALS AND OBJECTIVES

After the relevant partners are identified, the goals and specific objectives that are to be addressed through this component of the freeway system are developed. Goals are broad statements of the intent of the system or of one of its components, whereas objectives are specific statements about what the system or component of that system will attempt to accomplish. A given goal may have more than one objective specified to reach that goal. Table 6-2 lists examples of goals and objectives that the team might develop for HOV facilities.

ESTABLISH PERFORMANCE CRITERIA / MOES

Performance criteria and measures-of-effectiveness need to be identified in order to assess the extent to which HOV treatments are meeting goals and objectives. Table 6-3 lists suggested objectives and measures of effectiveness.

Table 6-2. Examples of Goals and Objectives for HOV Treatments.

Category	Examples
Goals	• Produce a Better Operating Freeway • Increase the Person-Moving Efficiency of the Roadway Facility • Encourage Mode Change
Objectives	• Reduce User Travel Time • Reduce or Defer the Need to Increase Highway Vehicle Capacity • Improve Efficiency and Economy of Public Transit Operations • Reduce Fuel Consumption • Improve Air Quality by Reducing Air Pollution in a Corridor

Evaluations are necessary to ensure that the improvements are providing the desired benefits and that the expenditure of public funds is justified. Interest exists in the results of these evaluations among many groups, for example, transportation professionals, elected officials, and the general public. While there appears to be general agreement among transportation professionals that HOV facilities should be evaluated, a consensus does not exist regarding the most appropriate measures to use, the performance thresholds the projects should meet to be considered effective, or the preferred data collection techniques. The challenge to transportation professionals is to provide accurate and objective evaluations of HOV facilities that focus on key criteria and that can be easily understood by the different partners. Analyses and findings contained in several reports provide some guidance.(6-8)

DEFINE FUNCTIONAL REQUIREMENTS

The functional requirements of HOV treatments define specific actions or activities that are to be performed in order to achieve one or more of the objectives. The functions should be defined independent of the technology to be employed in the system, so that the focus is on *what* the system is designed to do rather than on *how* the system will be doing it. Table 6-4 presents examples of functional requirements for various objectives.

Example treatments include the following:

- HOV Lanes.
  - Facilities on separate rights-of-way.
  - Long-distance HOV lanes serving buses, vanpools, and carpools, and located within or adjacent to the freeway right-of-way.
- Priority Access at Ramps.
- Terminal Facilities.
- Preferential Parking.

IDENTIFY AND SCREEN TECHNOLOGY

It is appropriate to assess the actual technologies available to meet the functional requirements. The assessment can begin with the discussion of available treatments contained later in this module. Because of the high interest in HOV facilities, the Transportation Research Board, among others, frequently plans meetings to discuss

Table 6-3. Suggested Objectives and Measures of Effectiveness for HOV Facilities. [6]

Objective	Measures of Effectiveness
Improve the capability of a congested freeway corridor to move more people by increasing the number of persons per vehicle	• Actual and percent increase in the person movement efficiency • Actual and percent increase in average vehicle occupancy rate • Actual and percent increase in carpools and vanpools • Actual and percent increase in bus riders
Increase the operating efficiency of bus service in the freeway corridor	• Improvement in vehicle productivity (operating cost per vehicle-mile, operating cost per passenger, operating cost per passenger mile) • Improved bus schedule adherence (on-time performance) • Improved bus safety (accident rates)
Provide travel time savings and a more reliable trip time to HOVs utilizing the HOV facility	• The peak-period, peak-direction travel time in the HOV lane(s) should be less than the travel time in adjacent freeway lanes • Increase in travel time reliability for vehicles using HOV lane(s)
Favorable impacts on air quality and energy consumption	• Reduction in emissions • Reduction in total fuel consumption • Reduction in the growth of vehicle miles of travel (VMT) and vehicle hours of travel
Increase the per lane efficiency of the total freeway facility	• Improvement in the peak-hour per lane efficiency of the total facility
Not unduly impact the operation of the freeway mainlanes	• The level of service in the freeway mainlanes should not decline
Be safe and not unduly impact the safety of the freeway general purpose mainlanes	• Number and severity of accidents for HOV and freeway lanes • Accident rate per million vehicle miles of travel • Accident rate per million passenger miles of travel
Have public support	• Support for the facility among users, non-users, general public, and policy makers • Violation rates (percent of vehicles not meeting the occupancy requirement)
Be a cost-effective transportation improvement	• Benefit-cost ratio

Table 6-4. Examples of Functional Requirements for HOV Treatments.

Objective	Functions
Improve the capability of a congested freeway corridor to move more people by increasing the number of persons per vehicle	To support the HOV facilities, assist in the development of ridesharing programs
Provide travel time savings and a more reliable trip time to HOVs utilizing the HOV facility	Design facility so that incidents are appropriately handled (e.g., quick identification and removal)
Have public support	Involve public at appropriate stages during the process. Develop and execute a public relations campaign

the benefits, challenges, and other aspects of HOV treatments. Publications from these sources can provide additional information on treatments.

Factors that should be considered at this stage include cost (construction, operation, maintenance, replacement, etc.), operations and maintenance requirements, and personnel, equipment, and facility needs. The process for identifying and screening different technologies for inclusion in a freeway management system is often iterative, because there are multiple ways that different technologies can be combined to achieve an objective. For example, decisions made about an HOV treatment can influence decisions made about surveillance techniques.

System Planning

In order for HOV systems and facilities to be properly integrated within the freeway system, system planning needs to occur at all levels, including strategic planning, long-range system planning, short-range planning, and service or operations planning. At the strategic planning level, freeway and transit agencies need to determine their roles, missions, and types of HOV services they want to provide in a metropolitan area. (This type of activity is discussed in detail in **Module 2**.) Through the long-range planning process, agencies can ensure that HOV facilities and services are incorporated into the future design of freeway systems and that funding for capital-intensive facilities are programmed into area transportation improvement plans. The short-range planning process can be used to assess administrative, funding, and service changes that need to occur usually within a 5-year period. Service or operations planning is an ongoing activity—often on a route or corridor basis— and is intended to identify improvements to improve service efficiency and effectiveness of HOV facilities.

Figure 6-2 illustrates a system planning methodology that can be used to identify HOV alternatives designed to service peak-hour person demand at the lowest total cost to the public, while at the same time, providing system continuity.[8] The public costs have been identified as travel delay, construction and right-of-way, and operation costs of the facilities. The methodology also recognizes that some

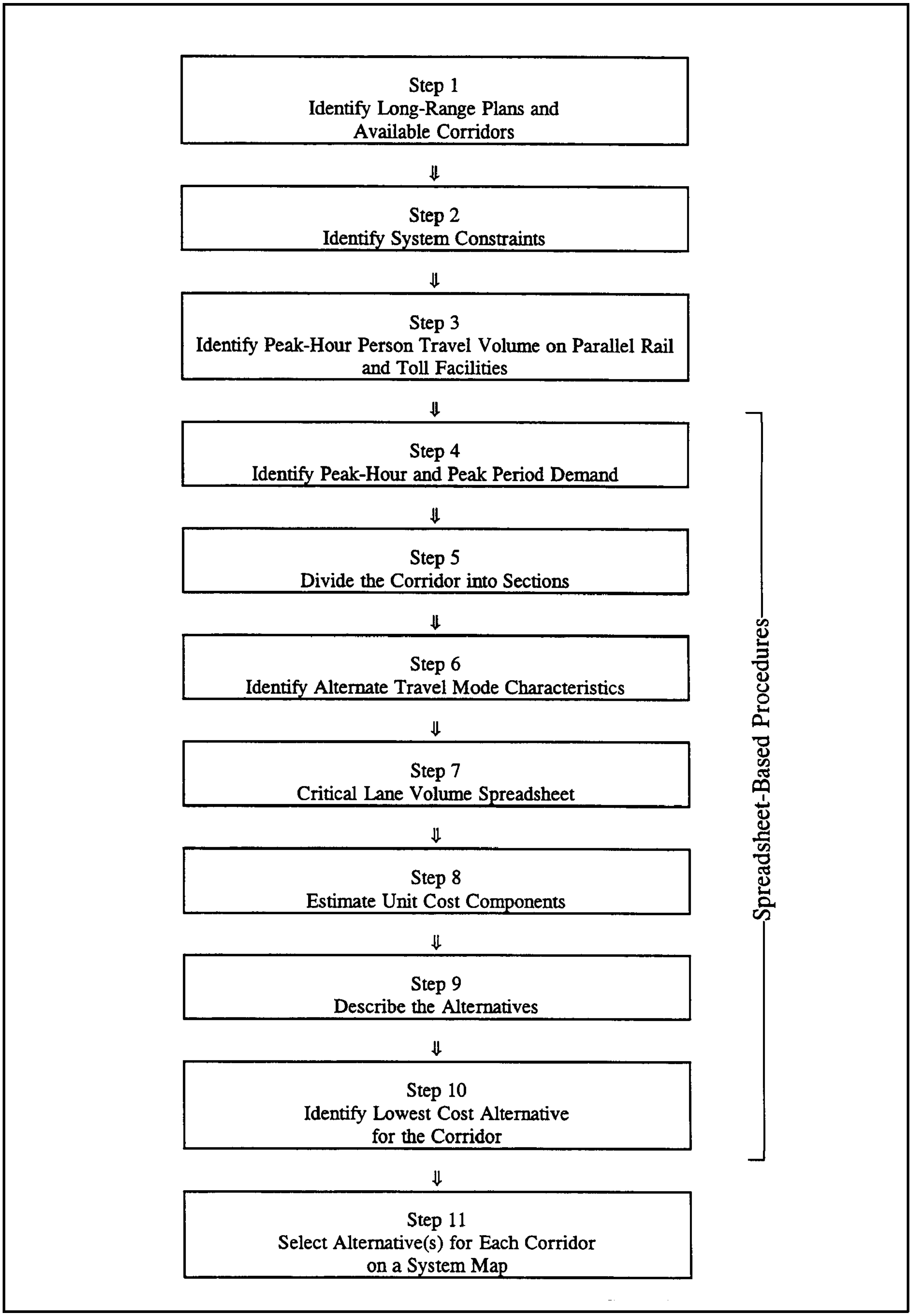


Figure 6-2. Multimodal System Planning Technique—Steps in the Process.[8]

motorists will change their mode of travel when given the opportunity to avoid congestion, resulting in more transit and carpool use. The methodology can be summarized in the following steps, which begin with corridor and system concerns, become more specific, and conclude with a system-level assessment of the results:

- Identify constraints in the corridor and the system.
- Estimate demand.
- Test alternatives for corridors.
- Examine results of individual corridors for system consistency and adjust improvements.

The methodology includes consideration of facilities such as parallel urban rail transit and toll highways, high-occupancy vehicle lanes, express freeway lanes, and general freeway lanes. The process can also incorporate operational and travel demand management improvements.

The multimodal system planning process includes a spreadsheet-based analytical procedure and several considerations before and after the spreadsheet operation. The technique generally follows an inside-outside geographic arrangement. System constraints (usually most frequent near downtowns) are initially identified. Individual corridors are analyzed and the alternatives optimized, possibly for several factors. The corridors are brought together on a system map, and the match points harmonized.

The system planning methodology provides information to quantify decisions regarding the most efficient expenditure of transportation funds for a multimodal system. It includes operational experience in the framework and provides a balance in difficult concepts such as congestion level and mode shift to ridesharing alternatives. It can optimize transportation systems based on the lowest cost to the public and also optimize within agency construction and operation budgets. The spreadsheet-based analytical program is open to user assumptions, and all default values are supported by documentation.

In practice, the outcomes of the corridor analyses vary depending on travel demand. Low demand corridors (less than 150,000 daily trips) where little or no construction is warranted are usually optimized with freeway general purpose lanes. Moderate demand corridors (up to 200,000 daily trips) may require some limited access express lanes, but the lowest public cost is usually achieved with only general purpose improvements. High demand corridors (in excess of 200,000 daily trips) are usually most efficient with a combination of HOV lane and freeway improvements.

IMPLEMENTATION

A natural result of the system engineering approach is the implementation of the plan. Issues that could be of concern with the implementation of an HOV treatment include the following:[5]

- **Scheduling.** If the HOV project is a retrofit, implementation scheduling can be complicated by a variety of unknowns, generally related to the policies and procedures of the various agencies involved. If the project requires daily monitoring (e.g., contraflow or reversible-flow operations), an additional 1 to 3 weeks following construction completion should be included for pre-operation testing.

- **Design/Construction Packaging.** Proper packaging of the project design can affect quality and cost. There are various reasons to segregate a project's elements into multiple design and construction packages. If the package is too large, competitiveness is reduced in the construction bidding process. If the improvement represents substantially different construction trades (i.e., roadway work versus electronic surveillance), it may also make sense to segregate the improvements to achieve the best responsiveness and quality of work. Conversely, it makes sense in projects involving HOV and adjacent freeway improvements, to combine common elements of work into the same construction packages. This simplifies construction management on the job site.

- **HOV Operation During Construction**. One of the most effective methods of cultivating an early market for an HOV project is to start offering preferential treatment during the construction phase. Additionally, this approach can be a cornerstone of the traffic management plan aimed at preserving corridor flow during construction activities. These benefits often outweigh the complications this approach creates for contractors and throughout the construction period.

- **Pre-Operation Testing**. Some pre-operation testing is desirable for any HOV facility. This period allows police to refine enforcement strategies and the operations team to make minor adjustments in the facility design prior to operation. For reversible-flow or contraflow projects, pre-operation testing is essential. At least 1 to 3 weeks is needed to check out any of the automated features that will be changed on a daily basis and acquaint bus operators, deployment staff, police, and others with how to handle daily operation, maintenance, and emergencies.

- **Operation.** Opening of a project should be preceded by significant public awareness efforts. Target users should be provided information on how to take advantage of the project, including maps, rules and regulations for use, and instructions on how to react in an emergency.

Prior to opening the facility to traffic, a plan must be devised for enforcing the restrictions on the facility. The plan should include how often, how long, and where enforcement activities should be performed.

EVALUATION

The final step in the design process is to evaluate the effectiveness of the HOV treatment. This should not be considered a one-time activity, but should be part of a periodic review of the effectiveness of the component and of the overall system. In addition to providing information to the sponsoring agencies on the effectiveness of the treatment(s), the information would be helpful in communicating the effectiveness of the project to the public and enhancing a general understanding of the role that the HOV project has performed.

Table 6-5 provides an overview of suggested objectives, data collection efforts, and corresponding measures of effectiveness for evaluating HOV facilities. The source of the information in this table contains an approach for conducting evaluations of freeway HOV facilities, including identification of appropriate evaluation objectives, corresponding measures of

Table 6-5. Suggested Objectives, Data Collection Efforts, and Measures of Effectiveness for Evaluating HOV Facilities. [6]

Objective	Veh. & Occup. Counts		Travel Time Runs		Surveys (1)			Corresponding Measure of Effectiveness (MOEs) (3)
	Freeway (2)	HOV Lane	Freeway (2)	HOV Lane	Freeway	HOV Lane	Other	
Increase occupancy	✶	✶			✶✶	✶✶	✶✶ (4)	Percent increase in peak-hour, peak-direction person volume; increase in average vehicle occupancy; and modal shift
Cost effective	✶✶	✶	✶	✶				Benefit-to-cost ratio
Travel time savings			✶	✶	✶✶	✶✶	✶✶(5)	Amount of travel time saving by HOV users; reliability of trip time for HOV users
Public Support		✶✶			✶	✶	✶✶(6)	Percent of users, non-users, and general public who approve of HOV facility; violation rates
Energy and air	✶	✶	✶	✶	✶✶	✶✶	✶✶(7)	Reduction in CO, HC, and NO emissions; reduction in energy consumption and noise level
Freeway operations	✶		✶		✶✶			Increase in peak-hour per lane efficiency of freeway
Safety	✶✶	✶✶					✶(8)	Number and severity of accidents; accident rate per million vehicle miles of travel and per million passenger miles of travel

✶ Indicates the top priority data collection efforts needed to evaluate the objectives.
✶✶ Indicates data collection efforts which ideally should be conducted, but are not absolutely necessary to evaluate the objectives.
1 Involves periodic use of surveys of HOV users (bus riders, carpoolers, and vanpoolers), non-HOV users in the general traffic lanes, and in some cases, the general public.
2 It is strongly suggested that this data be collected for both the freeway lanes adjacent to the HOV facility and the control freeway.
3 Some, but not necessarily all, of the suggested MOEs associated with gauging the attainment of the objectives are shown.
4 Vehicle and occupancy counts on alternate arterial routes to identify any changes in throughput for the corridor, counts at park-and-ride lots, and vehicle and occupancy counts on a “control” freeway.
5 Monitoring bus on-time performance and schedule adherence before-and-after implementation of the HOV lane(s).
6 Identifying violation rates for the HOV lane (i.e., those vehicles not meeting the minimum occupancy requirement). Monitoring complaints, media, and policy actions.
7 Monitoring air quality and noise levels along the corridor.
8 Identifying freeway accident rates and types before-and-after implementation of the HOV lane(s), as well as obtaining accident rates on the HOV facility.

effectiveness, data collection methodologies, and an evaluation process.[6]

6.3 TECHNIQUES AND TECHNOLOGIES

HOV FACILITIES

There are essentially four different types of high-occupancy vehicle (HOV) facilities used on freeways.

- ***Exclusive HOV Facility - Separate Right-of-Way.*** A roadway or lane(s) developed in a separate and distinct right-of-way and designated for the exclusive use of HOVs (see figure 6-3).
- ***Exclusive HOV Facility - Freeway Right-of-Way.*** Roadways or lanes built within the freeway right-of-way which are physically separated from the other freeway lanes but reserved for exclusive use by HOVs, at least during portions of the day (see figure 6-4).
- ***Concurrent Flow Lane***. A freeway lane in the peak direction of flow (normally the inside lane) that is not physically separated from the other freeway lanes but is designated for use by HOVs at least for a portion of the day (see figure 6-5).
- ***Contraflow Lane***. A freeway lane in the off-peak direction of flow (normally adjacent to the median) that is designated for use by HOVs traveling in the direction of peak flow for at least a portion of the day. Normally, the contraflow lane is "separated" from the off-peak (or opposite) flow by insertable cones, pylons (see figure 6-6), or movable concrete barriers.

Operational Considerations

The importance of incorporating operational considerations into both the planning and design process for HOV facilities cannot be overstated. The operation of an HOV facility is critical and should be considered when making planning, design, and implementation decisions. Also, consideration must be given to a range of needs involving support services and facilities, such as park-and-ride lots, bus service planning, marketing rideshare matching, and enforcement. Following is a summary of several operational considerations as discussed in the AASHTO *Guide*.[10]

Figure 6-3. Examples of Exclusive HOV Facility - Separate Right-of-Way. [9]

Figure 6-4. Examples of Exclusive HOV Facility - Freeway Right-of-Way. (9)

Figure 6-5. Examples of Concurrent Flow Lane. (9)

Figure 6-6. Examples of Contraflow Lanes. [9]

HOV Roadway Operations

The operation of separated HOV roadways may be reversible or two-way. The facility can be restricted to HOVs during peak periods only or throughout the day. The latter is less expensive to sign and operate. Limiting access to a reversible HOV facility is crucial if the facility is to be operated in a safe and efficient manner. A system of gates should be considered at each end to prevent wrong-way traffic from entering the facility. In addition to these features, this type of facility should also have a system of variable message signs (VMS) which inform commuters as to the operational status of the facility (open or closed).

Operating Efficiency

The reduction of user travel time is the commonly used measure for assessing the benefits of HOV facility operation. A vehicle breakdown on an HOV facility can be anticipated to occur approximately every 64,000 vehicle-kilometers (40,000 vehicle-miles) traveled. A disabled vehicle will cause a decrease in traveling speeds or, in extreme cases, a total blockage of the facility. Figure 6-7 illustrates the consequences of a 15-minute total blockage on an HOV facility on a separated roadway having a demand of 6,000 persons per hour and a capacity of 12,000 persons per hour. As shown, the 15-minute blockage causes 22,500 person-minutes of delay, and it will take 30 minutes from the time of blockage until the queue totally dissipates.

Considerations for 2+ Versus 3+ Occupancy Requirement

HOV facilities should be implemented in a way that balances the flexibility of HOV growth and the public perception as to the use of a facility. An initial minimum vehicle occupancy requirement must be selected to optimize the efficiency of the facility. The selection must allow for growth in traffic volumes as more commuters choose to switch to carpooling arrangements and take advantage of the travel time and fuel savings. Title 23 United States Code 102(A) allows State departments of transportation to establish the minimum occupancy requirements for vehicles operating on HOV lanes; except that no fewer than two occupants per vehicle may be required and that motorcycles and bicycles shall not be considered single occupant vehicles.

Retaining the potential to carry more people over time offers important operational flexibility. At the same time, though, public perception of the adequacy of HOV lane usage must also be addressed. Peak hour

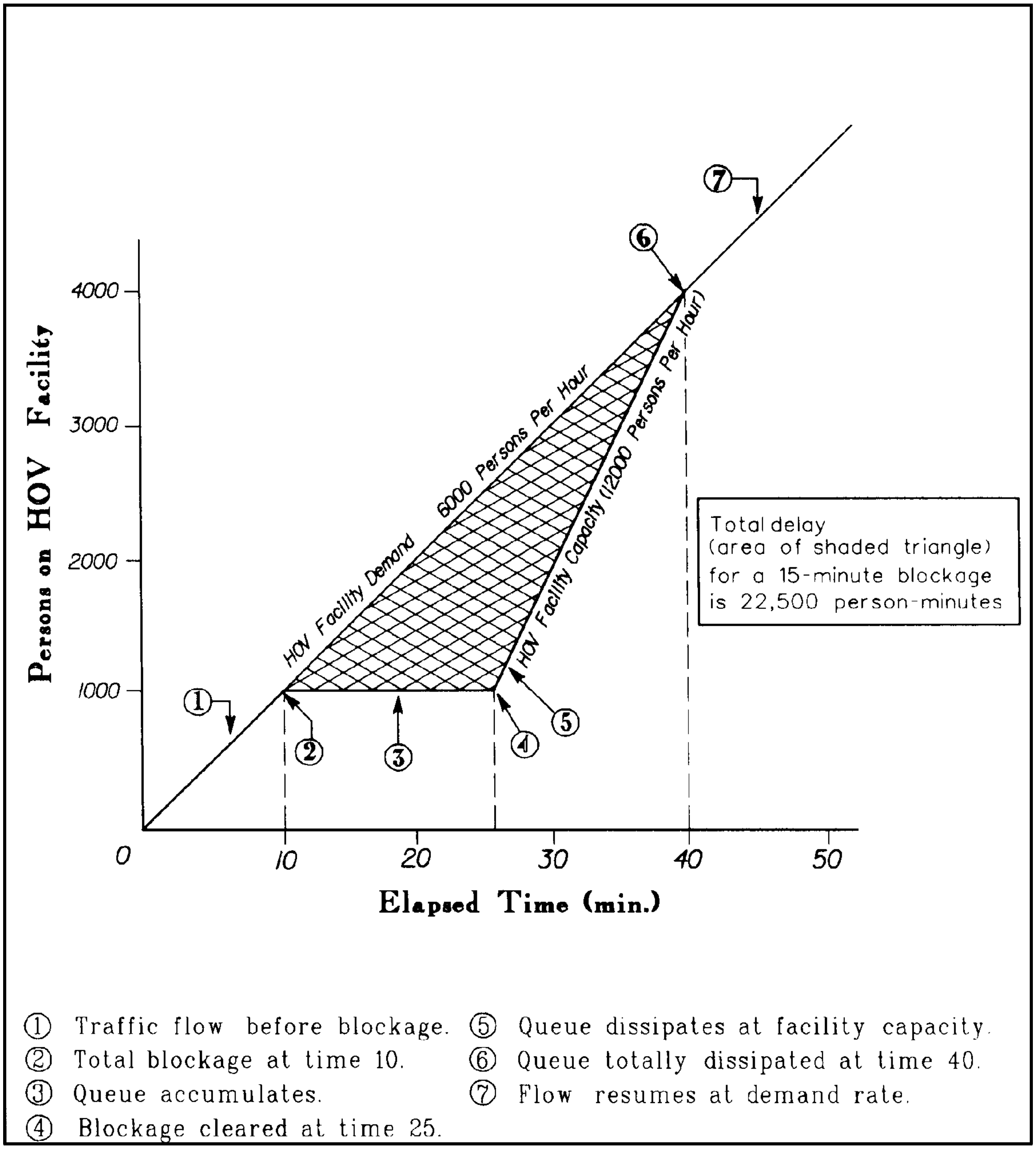


Figure 6-7. Example of Delay on an HOV Facility Due to a Total Blockage Incident. [10]

HOV traffic volumes need to be high enough to help mitigate public concerns over underutilization of HOV facilities. The positive aspect of 2+ eligibility is that a staged resource of commitment to ridesharing is being established. Less work is involved in forming a 2+ carpool versus a 3+ carpool, and the base volume to draw from is considerably greater. There may be less eventual resistance to adding a third passenger than to forming an initial 3+ carpool.

Subsequent changes in occupancy requirements need to be weighed with projected future demand. To go from 2+ to 3+ occupancy could reduce vehicular demand by as much as 75 to 85 percent.

This could be severe if only a 10 to 20 percent reduction in demand is necessary for the near future. A new HOV 3+ lane typically may carry only a few hundred peak-hour vehicles, while an adjacent freeway lane is carrying 1500 to 2000 peak-hour vehicles. Even though the HOV lane may be carrying more peak-hour person trips than an adjacent freeway lane, the traveling public may perceive the lane to be underutilized. Consideration should be given to changing from 2+ to 3+ occupancy when the level of service of the HOV lane is approaching Level of Service D.

In other words, the flexibility to change occupancy requirements is a strong operational management tool. However, changing these requirements frequently or varying the requirement by time of day may create enforcement problems and public resistance.

Hours of Operations

An HOV facility may be operated only during peak periods only or for 24 hours. A number of factors, including geometric design, volumes of HOV and mixed-flow traffic, and hours of congestion will influence HOV operating hours.

Twenty-four hour HOV use of priority facilities is sometimes preferred, because violations tend to be lower and there is less motorist confusion. Also, 24-hour use may provide a greater overall incentive for the formation of new carpools. Some HOV facilities, such as reversible lanes, may not be conducive to 24-hour operation. The hours of operation for reversible facilities must allow time for a variety of necessary functions, such as clearing the lane, moving gates, and changing signing.

Part-time use of a shoulder as an HOV facility should be implemented only after careful consideration of operational and safety problems. The shoulder HOV facility differs from a part-time HOV lane that reverts to mixed-flow use during off-peak periods. The shoulder facility requires special delineation and signing, and involves separate enforcement problems for both peak and off-peak periods. Motorists may tend to use the shoulder as a freeway lane during off-peak hours when it should be used as a shoulder.

Design Elements

Design Speed

A purpose of HOV facilities is to provide a travel time savings for HOVs. Therefore, it is preferable to use a design speed for the HOV facility that is comparable to the adjoining freeway. AASHTO freeway standards for design speed should be used to provide for a high level of service. The design of the facility should consider the specific physical dimensions and operating characteristics of the vehicle types that are expected to be well represented in the vehicle mix. For example, the difference in braking and acceleration characteristics may suggest a different roadway geometry than just using passenger cars.

Cross Section Width

Following is a summary of dimensions used in the design of transit ways.[11] The preferred cross section for single lane at-grade, one-way transitways is a 3.6-m (12-ft) travel mainlane and 1.5-m (5-ft) clearance offsets (shoulders), while the usual cross section is 3.6-m (12-ft) travel mainlane and 1.143-m (3.75-ft) clearance offsets (shoulders). A total minimum width of 6.1 m (20 ft) is recommended for single-lane facilities, as this will allow a disabled vehicle to be passed. Reduced cross sections do not provide the passing capability, and therefore are recommended only for short sections, approximately 610 m (2000 ft) or less, that involve physical constrictions.[12] For multiple lane at-grade, two-way facilities, the travel mainlanes are 3.6 m (12 ft), the center shoulder separations are 3.0 m (10 ft), and the clearance offsets are 0.6 m (2 ft).

HOV lanes should have a minimum pavement width of 3.6 m (12 ft). The pavement should be widened through horizontal curves to account for the offtracking of buses. A minimum width of 4.0 m (13 ft) is recommended for HOV ramps. The typical cross slope for a transitway is two percent, the same cross slope found on most freeway mainlanes.

To allow water to drain, a minimum grade of 0.35 percent should be provided. A maximum grade of 6 percent is recommended to prevent buses from slowing down on the HOV lane. The desirable superelevation is 0.04 to 0.06 for speeds of 64 to 80 km/h (40 to 50 mph) and 0.06 to 0.08 for speeds of 80 to 97 km/h (50 to 60 mph). Vertical clearances are 4.42 m (14.5 ft) minimum and 5.03 m (16.5 ft) desirable, while lateral clearances are 0.6 m (2 ft) minimum and 2.4 m (8 ft) desirable.

Vertical Clearance

Vertical clearance to structures passing over the HOV facility should desirably be the same as for the adjacent freeway at 5.03 m (16.5 ft). While this is more than sufficient allowance for the maximum height of a standard transit bus at 3.429 m (11.25 ft) (double-deck bus is 4.32 m [14.2 ft]), it does allow for the possibility of emergency use or for future use of other types of vehicles, including large commercial trucks. In situations of restricted vertical clearance, a reduced (usual) clearance of 4.42 m (14.5 ft) is generally acceptable. This includes some allowance in vehicle operation and future pavement resurfacing.[4]

Signs and Markings

Signs and markings should conform to the *Manual on Uniform Traffic Control Devices (MUTCD)* to the fullest extent possible.[13] Preferential lane markings should be used to indicate that the lanes are restricted, with supplemental signs or signals conveying the specific restrictions. At the entrance to reversible facilities, particular attention must be paid to the control devices. In addition to static signs, variable message signs may be necessary. These should be supplemented with gates or barriers to further prevent entry by vehicles going in the wrong direction or to allow only authorized vehicles by special designation to enter the facility.

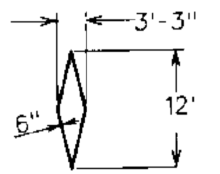
Signs. Regulatory signing for HOV lanes should follow the standard regulatory signing principles (e.g., black legend on white background, rectangular shape, and reflectorized or illuminated). The diamond symbol (white on black background) should be incorporated into the sign format. Guide signing may be necessary on HOV lanes that have designated ingress, ingress/egress, or egress points to inform the motorist of the appropriate HOV lane entry or exit point to use. The guide signing should follow the standard guide signing of the *MUTCD*. The diamond symbol should also be incorporated into the sign format, preferably in the upper left corner of the sign.

Figure 6-8 gives sample signing and pavement markings for HOV lanes used by Caltrans, along with some general applications criteria.

Markings. When a lane is assigned full- or part-time HOV use, HOV lane markings are

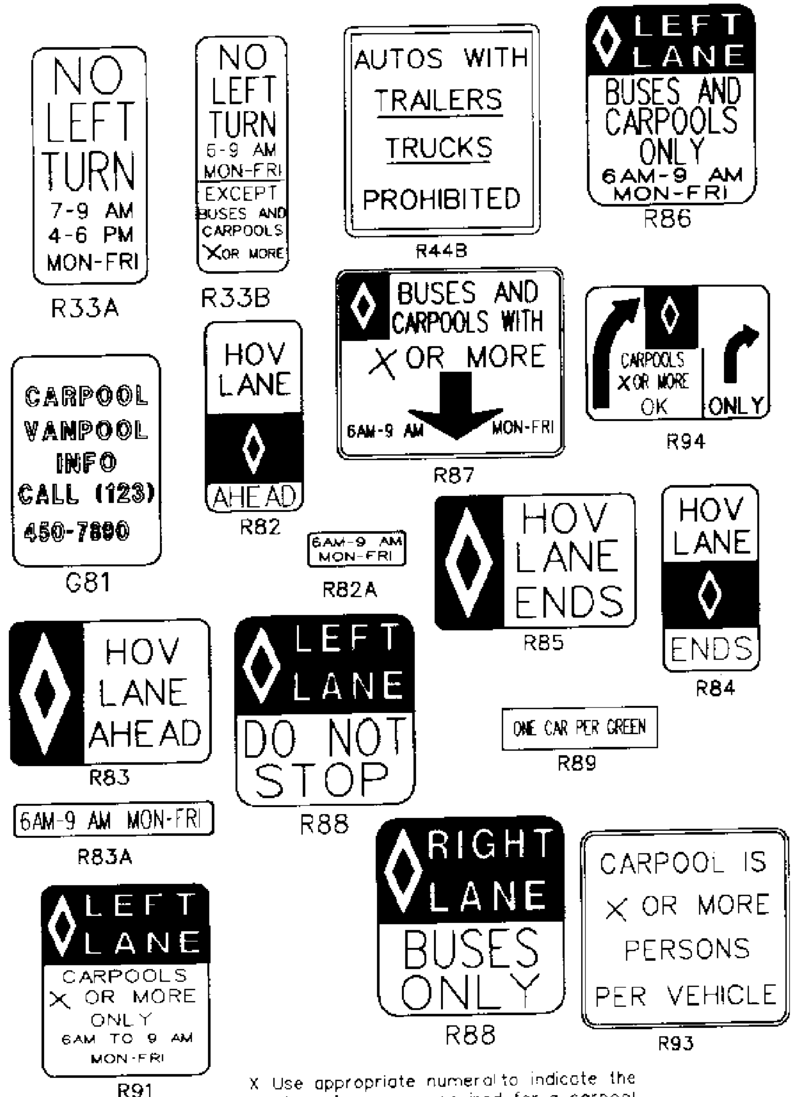
HOV PAVEMENT MARKING AND SIGNING NOTES

1. Two advance carpool signs, R94, should be installed on local street when striped for mandatory right turn.
2. Two or more carpool signs, R33B, should be installed on local streets (with concurrence of local agency) wherever left turns are restricted to carpools during peak hours.
3. Two carpool signs, R91, should be installed on extra long entrance ramps with two Detail 'A' pavement markings.
4. Four or more carpool signs, R91, should be installed on extra long ramps with two or more Detail 'A' pavement markings.
5. Spacing of Detail 'A' may be as close as 80 feet on city streets, while a spacing of 1/4 mile may be appropriate for a freeway.
6. Signing and pavement marking details and notes shown on this sheet should be used wherever feasible. Exceptions and proposed experimentation with other signs and markings should be reviewed in advance by the Operations Unit.
7. The bus-carpool lane on the freeway entrance ramp may be either on the left or right side.
8. Additional required signs and markings are shown in the Caltrans Traffic Manual, Section 4-05, Ramp Terminal Signing.
9. A number may be placed in the center of the Detail 'A' pavement symbol to indicate the number of persons required for a carpool.
10. Posted time is not required for ramp bypass lane metered by traffic signals.
11. The pavement legend "CARPOOL LANE" may be used to supplement the Detail 'A' installations on new projects. The word message should then be allowed to wear out.
12. For 24 hour HOV operations, time restrictions are deleted.



DETAIL 'A'

(See Note 9)



X Use appropriate numeral to indicate the number of persons required for a carpool.

Figure 6-8. Sample Signing and Pavement Markings for HOV Facilities.[10]

necessary. The HOV lane marking should be an elongated diamond placed along the longitudinal center of each restricted lane (see figure 6-8). The marking is intended to convey that a restriction on the use of the lane exists, and it is supplemental to the signs or signals conveying the specific restriction. Signs or signals should be used with the HOV lane markings.[10]

The frequency with which the marking is placed is a matter for engineering judgement based on prevailing speed, distance between interchanges and other considerations necessary to adequately communicate with the driver. A spacing of 0.40 km (0.25 mi) would be appropriate for most freeway situations, except on crest vertical curves where a shorter spacing should be used. Initially, the markings “CAR” “POOL” “LANE” may be painted between the diamond symbols on new projects to supplement, but not substitute for, the HOV lane markings. The word markings should then be allowed to wear out once drivers become familiar with the facility.[10]

The striping pattern for the lane line between the HOV lane and the adjacent mixed-flow lane should be in accordance with the *MUTCD*.[13] Typical HOV lane striping and pavement marking schemes are shown in figure 6-9. This figure also provides examples of signing appropriate for concurrent HOV lanes.

Enforcement

Goals and Objectives

An objective of enforcement by police officers on HOV facilities is to maintain the operational integrity and safety of the facility for those high occupancy vehicles designated or authorized to use it. In this regard, detection and apprehension of violators, and effective prosecution of violators, are essential. Therefore, law enforcement personnel with full capability to issue citations must be employed on HOV facilities. In addition, police officers help ensure the safe and efficient operation of the facility. Depending on the type of facility and priority users, the potential safety and operational problems caused by vehicle breakdowns, wrong way movements and/or other vehicles’ encroachments into the HOV facility may have an adverse impact on operations and must be a concern of the enforcement authority.

Table 6-6 summarizes selected goals and objectives of enforcement personnel, as well as strategies for implementation and measures of effectiveness.

A 1988 Texas Transportation Institute study of the enforcement procedures for HOV lanes determined the following key concepts related to effective HOV enforcement:[14]

- The level of enforcement needed is dependent upon facility type. In general, concurrent flow facilities require more enforcement than do separated roadway and contraflow facilities.
- To be effective, an officer must have a safe and convenient place to issue citations or warnings. The enforcement activity should be in view of HOV users so that they can see when the lane restrictions are being enforced; however, it should not interfere with traffic on the HOV and mixed-flow lanes.
- To preclude high violation rates, a highly visible enforcement presence has to be maintained at a level where potential violators and legitimate users believe that violators have little chance to use the lane without getting caught.

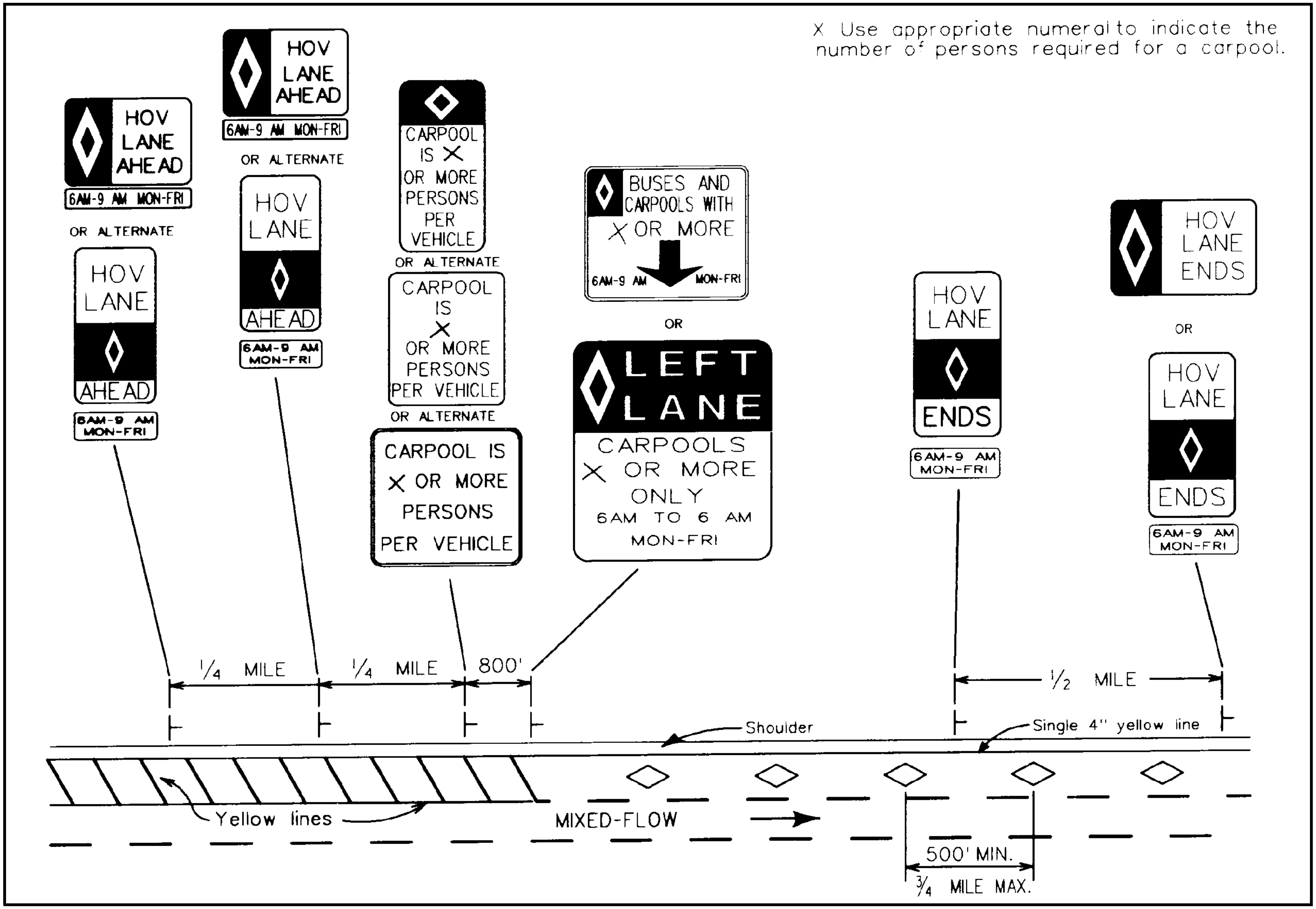


Figure 6-9. Typical Contiguous Concurrent HOV Lane w/o Buffer Signing and Pavement Markings.[10]

Table 6-6. Goals and Objectives of Enforcement Personnel.

Goal	Objectives	Strategies	Measures of Effectiveness
Maintain operational integrity	Help minimize delay	Strict enforcement of occupancy require-ments	Violations
	Minimize violation rates	Clear communication of nature of facility	Violation rates
		High visibility of enforcement officers	Travel times
		Swift, safe removal of violators	
Maintain safe operation	Minimize accidents	Strict enforcement of operating rules	Accidents
	Help minimize incident response and clearance times	Clear communication of nature of facility	Accident rates
		Swift, safe removal of violators	Incident response and clearance times

- On limited access facilities, diverting potential violators before they can traverse some part of an HOV lane can be safer and more efficient than apprehending them after the fact. Whenever possible, enforcement areas should incorporate this concept.

Methods

Where enforcement is difficult to accomplish, or perceived as being unsafe, police may avoid apprehending violators, resulting in increasing numbers of illegal vehicles using the lane. Where enforcement has been a problem, 60 percent or more of the vehicles that used the lanes were violators. Experience suggests that steady doses of routine enforcement, combined with moderate application of special enforcement, can generally keep violation rates on exclusive HOV facilities in the 5 to 10 percent range. Heavy, consistent doses of special enforcement would be necessary to have violation rates below 5 percent. There are locations where no amount of enforcement can bring violation rates to an acceptable level.[10]

In some metropolitan areas, programs have been initiated where motorists can call in to report HOV facility violators. Appropriate literature is sent to frequent violators, and enforcement personnel can make a point of watching for these vehicles in the HOV lane. These “so called” HERO programs have been helpful in reducing violation rates. Also, a system of video cameras combined with officer observation may be considered. Another factor that will have a positive

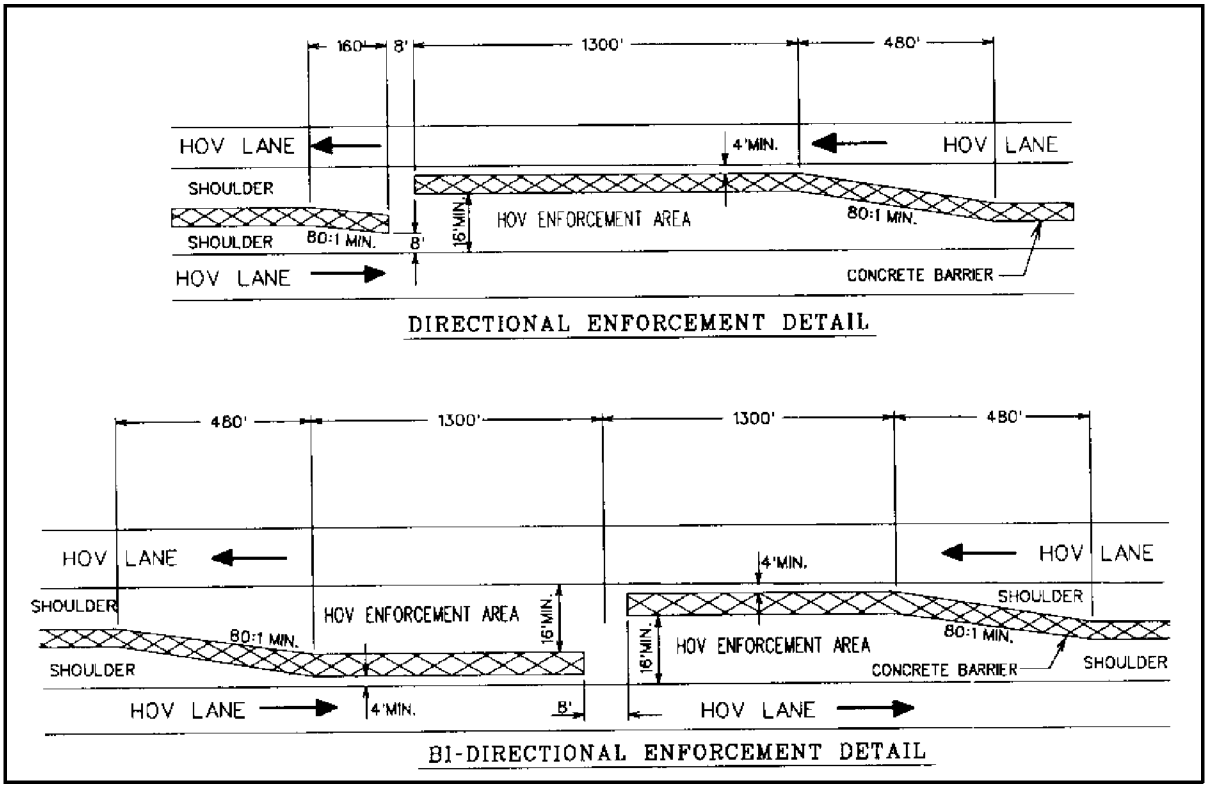


Figure 6-10. Median Enforcement Area for Median 6.7 to 8.8 m (22 to 29 ft) Wide.[10]

impact on the violation rate is the cost of the fine for a violation. Fines exceeding $250 for first offenders have been used, significantly lowering the violation rate.

Enforcement Area Design

When totally new concurrent HOV facilities are to be built and there is adequate width for a median 9 m (30 ft) or wider, consideration should be given to providing a 4.3-m (14-ft), paved median shoulder in both directions as a continuous enforcement area. When facilities are operating at high speeds (81 km/h (50 mi/h) or above), enforcement officers are uncomfortable having to stop and approach another stopped vehicle in less width than this.[10]

On other facilities where the median width is less than 9.2 km/h (30 ft) but equal to or greater than 6.7 m (22 ft) wide, it is possible to accommodate enforcement pockets by narrowing the median shoulder on alternating sides of the center barrier, which permits on-line enforcement. Figure 6-10 shows possible designs for enforcement areas. Closely spaced raised pavement markers could be used to provide added delineation between the enforcement area and the HOV lane in order to improve safety of the enforcement area. California, for example, uses raised pavement markers spaced out at 1.8 m (6 ft) along the edgeline to provide an audible warning to those entering the enforcement area.[10]

Where the median width is less than 6.7 m (22 ft) and enforcement pockets are required, it will be necessary to shift, in one or both directions of travel, away from the centerline in order to obtain the minimum width to accommodate a minimum 4.3-m (14-ft) wide pocket, 0.6-m (2-ft) barrier, and 0.9-m (3-ft) offset to the barrier from the opposing HOV lane. Tapers for lane shifts should be 115:1 or greater. Conceptual design is shown on figure 6-11.

Pockets should be no more than 3.2 to 4.8 km (2 to 3 mi) apart, and should be located between interchanges to avoid interference from interchange structures and also to minimize both the distraction to other drivers and the lane changes taking place at any one time. Pockets should be located to provide minimum sight distance requirements.[10]

ACCESS

Ramp Connections

Types of ramp connections to HOV facilities include the following:

- ***Slip Ramps*** - The at-grade slip ramps are the easiest and least expensive to build. An opening large enough for normal merge/diverge maneuvers is placed in the barrier. This type of ramp is usually from a park-and-ride lot to the frontage road, the freeway, or the HOV lane (see figure 6-12). Elevated slip ramps are also used in some locations (see figure 6-13).

- ***Flyover Ramps*** - The second type of park-and-ride connection is the flyover ramp (see figure 6-14). This ramp resembles an elevated freeway ramp, except that flyover ramps can be either one- or two-way. The elevated flyover ramp is directly connected from the park-and-ride lot to the HOV lane. Because the flyover ramp does not create a tee intersection, fewer conflict points exist.

- ***Grade Separated Interchanges*** - Grade separated interchanges are more expensive than at-grade ramps, but they provide greater flexibility and movement. They are basically aerial tee intersections that can be either one or two directional (see figure 6-15). Acceleration and deceleration lanes should be included. Grade separated interchanges allow vehicles to travel directly from the park-and-ride facility to the HOV lane.

Design

The design of access connections depends on the decision of how to interface high occupancy vehicles with general purpose vehicles on and off the freeway.[10] Several options are available. One option is to connect the HOV facility directly to the freeway with the use of elevated flyover ramps or at-grade slip ramps. Another option is to link the HOV facility directly to the frontage road or surface street system. Of course, transition treatments must be provided in some manner at both ends of the roadway.

If feasible, the terminal connections to HOV facilities from the adjacent freeway mainline should be made with flyover ramps at both terminal end connections. This allows buses and other vehicles using the HOV facilities to exit and enter the freeway mainline on the right instead of having to enter the inner high speed lanes. This eliminates the high-speed lane merge, which is inherently more difficult to execute, especially for HOV traffic such as buses and vans. Depending on the interchange spacing, it could also eliminate the need for the HOVs to make several rapid lane changes in order to access the HOV lane or exit the freeway.

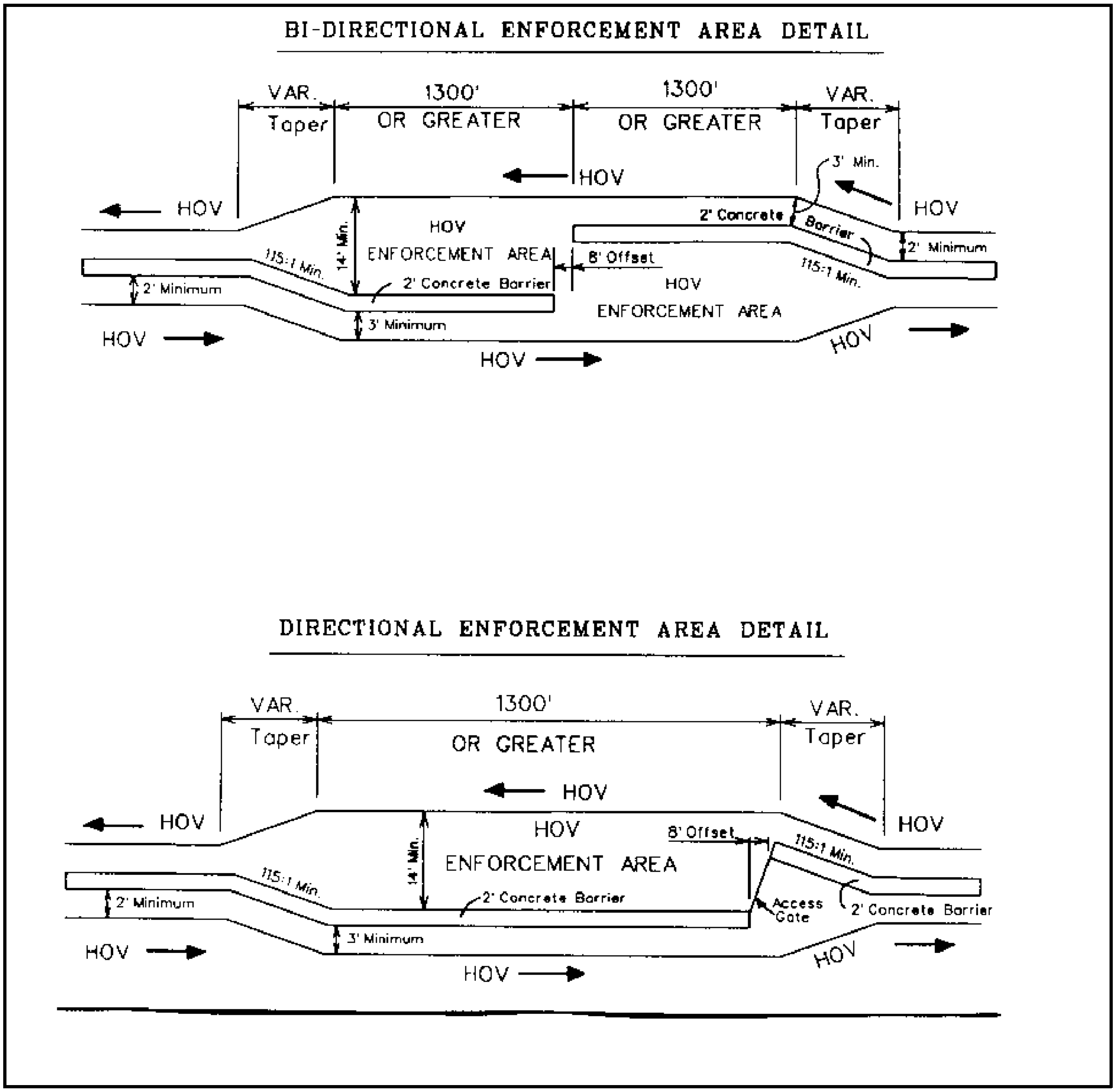


Figure 6-11. Median Enforcement Area for Median Less than 6.7 m (22 ft) Wide.[10]

Figure 6-12. Slip Ramp. [9]

Figure 6-13. Elevated Slip Ramp. [9]

Figure 6-14. Flyover Ramp.[9]

Figure 6-15. Grade Separated Interchange.[9]

Figure 6-16 shows typical flyover ramps connecting the HOV lanes to the righthand lanes of the freeway mainline. Where limited right-of-way and/or high costs prohibit the use of elevated flyover ramps, at-grade slip ramps can be used. At-grade slip ramps are also appropriate where the HOV facilities are reversible. This type of slip ramps terminal is particularly applicable to temporary or phased HOV lane implementation. Figure 6-17 illustrates the general concept of how an HOV facility with slip ramps can be incorporated into the freeway median. Since the HOV lanes shown are reversible, signing and/or barriers will be required to eliminate the wrong-way entry or exit. If traffic patterns warrant, separated HOV facilities should tie in to the existing street system within the central business district.

Direct ramps from a median HOV facility may be expensive and result in operational problems. However, they are preferable to merging HOV traffic with other freeway traffic in advance of the central business district, provided conditions permit. This concept is shown in figure 6-18 with connections into surface streets. It may also be desirable to connect the HOV facility to the through lanes of the freeway to provide for the through movement motorist. From outer areas, connections may be provided into freeway frontage roads for either collection or distribution of high-occupancy vehicles. Figure 6-19 illustrates the use of HOV flyover ramps to the freeway frontage roads. Where the HOV lanes are reversible, signing and/or barriers will be required to eliminate the wrong-way entry.

Intermediate connections to the HOV facility allow access on and off the facility to the through lanes of the freeway at critical locations, transit transfer centers, park-and-ride lots, and park-and-pool areas. These connections may be made at-grade with intermediate slip ramp openings or by grade separated interchanges.

All terminal and intermediate access connections should have high design standards. Tapers on entrance and exit ramps should be designed the same as for other freeway ramps, except that special consideration should be given to the acceleration and deceleration characteristics of loaded buses. This is especially critical where ramp grades are significant. Very long, gradual tapers should be avoided on exit ramps, as traffic may inadvertently follow the taper, assuming it is the main roadway. Ramps that connect to adjacent facilities or to cross streets should be designed to the same standards as comparable facilities that connect freeways to cross roads.

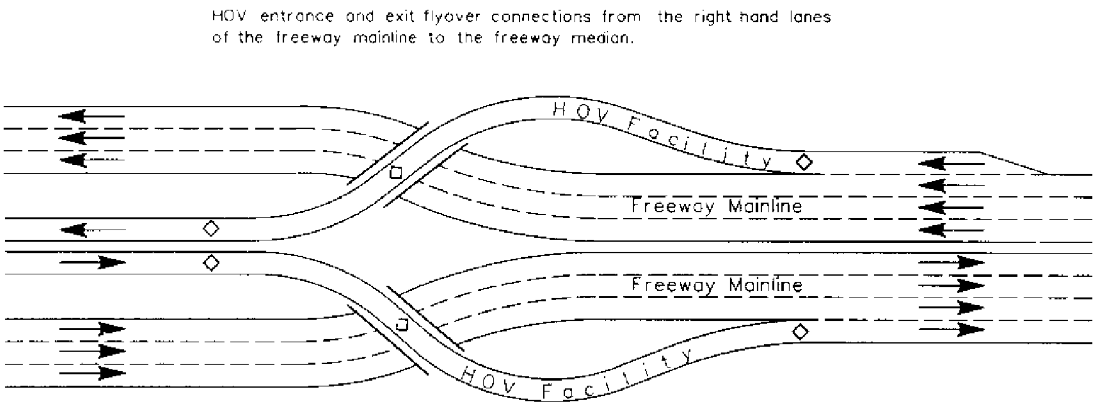


Figure 6-16. Terminal Flyover Connection to Freeway Mainline.[10]

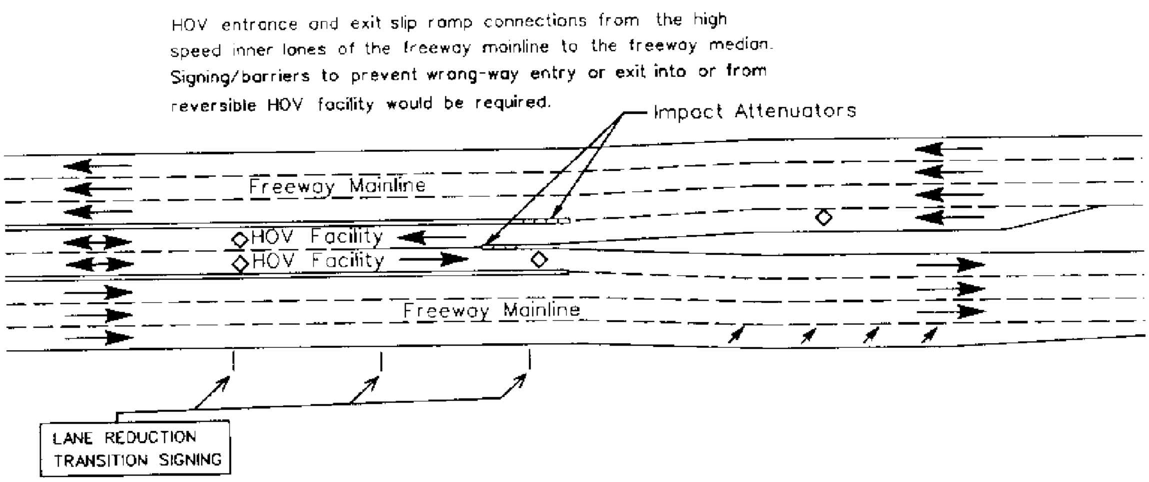


Figure 6-17. Terminal Slip Ramp Connection.[10]

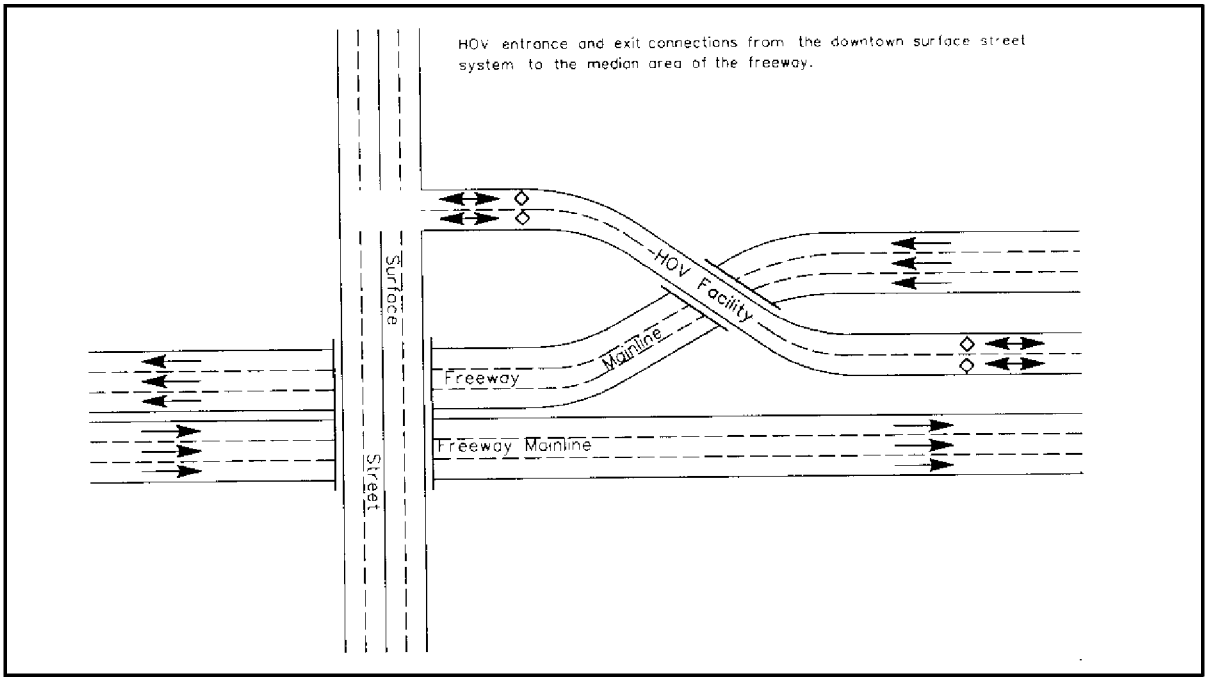


Figure 6-18. Terminal Flyover Connection to Surface Street System.[10]

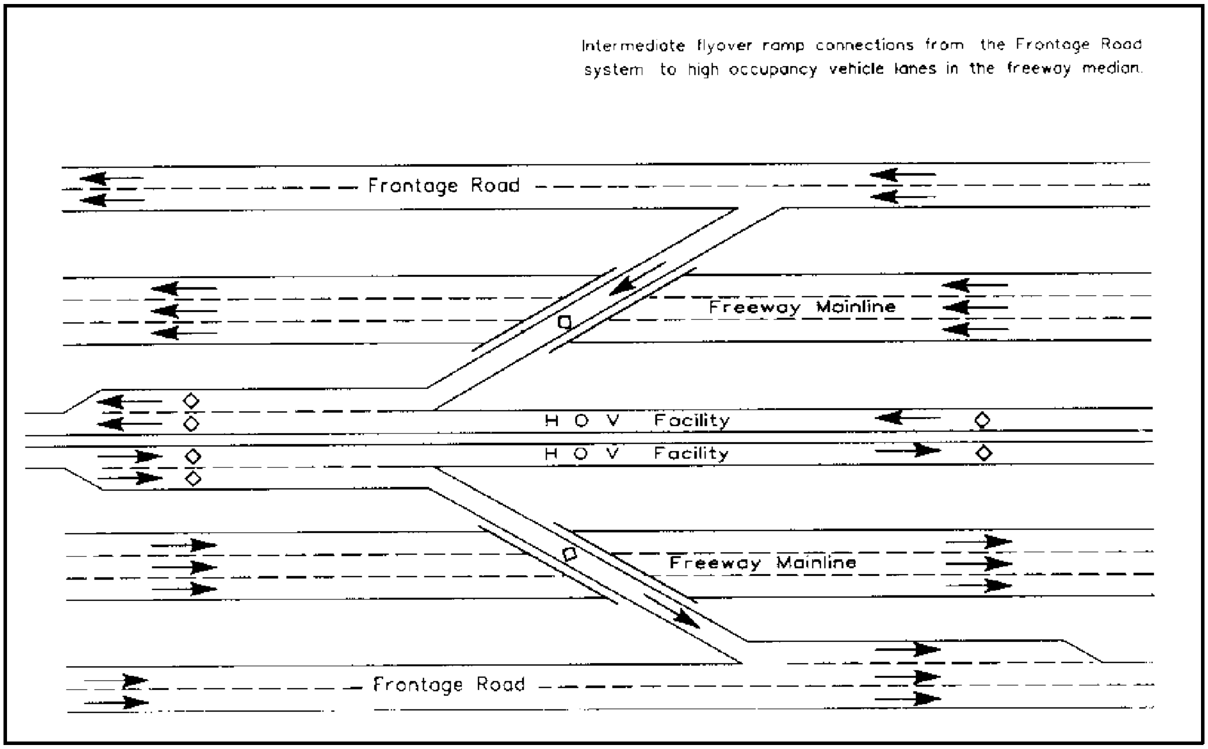


Figure 6-19. Intermediate Flyover to Frontage Road.[10]

Ramps are generally designed for speeds between 0 and 64 km/h (0 and 40 mi/h). Acceleration and deceleration lanes should be used for all types of HOV ramps. A minimum width of 4.0 m 13 ft) is recommended for HOV ramps. The minimum grade is the same as on the HOV lane, 0.35 percent; the maximum grade, however, is 8 percent.[11] Additional information is provided in the latest edition of the *Green Book*. [15]

PRIORITY ACCESS

Ramp Metering

Ramp meters are installed on freeway entrance ramps to do the following:

- Maintain uninterrupted, noncongested flow.
- Increase safety and efficiency by spreading out platoons of entering vehicles.
- Reduce congestion at the mainline ramp merge point.
- Limit amount of traffic entering the freeway so that demand for any section does not exceed capacity.

Ramp metering accomplishes these objectives by means of traffic signals on the entrance ramps that control the rate at which vehicles enter the freeway to maintain a balanced demand-capacity relationship. Usually, the rate of entry to the freeway is adjusted in response to the level of congestion or capacity available on the freeway. As freeway congestion increases, the rate at which vehicles are allowed to enter the freeway decreases. Also, excess freeway vehicular demand is encouraged to shift to alternative routes, to less congested time periods, or to HOV modes of transportation.

Ramp metering provides an opportunity to give priority treatment to, and encourage the use of, HOVs. This priority treatment can be in the form of a bypass of the meter or a preferential metering rate as compared with that of the general purpose ramp-metered lane. These treatments can be used in conjunction with mainline HOV lanes or where a freeway management system maintains an acceptable level of service and no HOV lanes are provided.

These bypass lanes can be restricted to buses only or can be made available to all HOVs. The decision on eligibility for use of the bypass should depend on the goals of the community, the number and types of vehicles that will use the bypass, and geometric conditions at the site affecting enforcement and operation of the ramp.

Bypass Lanes

The configuration of an HOV bypass lane can be that of a two-lane entrance ramp which tapers to a single-lane ramp prior to the merge with the freeway mainline, or a separate HOV bypass lane which merges with the entrance ramp downstream of the ramp meter. Figure 6-20 shows an example of the two-lane entrance ramp bypass.

The design of the ramp meter bypass should be determined by the conditions at each location. Bypasses should be 3.7 m (12 ft) wide with full ramp shoulders where possible, and should extend 91 m (300 ft) beyond the metering signal to permit HOVs to merge with normal ramp traffic. The ramp bypass traffic should merge first with regular ramp traffic, and then with freeway traffic.[10]

Figure 6-20. Two-Lane Entrance Ramp with HOV Bypass. [9]

Signs

For the two-lane entrance where one lane is designed as an HOV bypass lane, signs and pavement markings need to indicate the use of the right or left lane as the bypass lane. Such regulatory signs typically bear the legend "RIGHT/LEFT LANE BUSES AND CARPOOLS ONLY," and have the diamond symbol on the sign. The diamond symbol is also used as a pavement marking in the bypass lane. If a separate HOV bypass lane is constructed, the entrance to the bypass lane often has a sign installed reading "BUSES AND CARPOOLS ONLY," and the white-on-black diamond symbol.

Markings

Pavement markings have three major functions in a ramp metering HOV bypass installation:

- Indicate to drivers where to stop.
- Guide vehicles to form a single lane if the ramp begins as two lanes and tapers to one.
- Indicate the HOV bypass lane.

Ramp meter bypasses may be separated from the mixed-use lane by solid white pavement markings 20 cm (8 in) wide or wider. Diamond symbols should be used at 23 to 31 m (75 to 100 ft) intervals. Word pavement markings such as "CARPOOL ONLY", or "BUS ONLY" can also be used as appropriate and should be supplemented with signs.[10]

PARK-AND-RIDE FACILITIES

Park-and-ride facilities are an integral part of a multimodal transportation system. The purpose of these facilities is to provide a location for individuals to transfer from a low-occupancy mode of travel to a high-occupancy mode of travel. Park-and-ride facilities are typically provided in conjunction with transit services.

Most of the HOV facilities in operation around the country are connected either directly or indirectly to park-and-ride lots. For HOV lanes, transfers at park-and-ride lots are usually made from a vehicle to a bus; however, transfers may also occur from single-occupancy vehicles to carpools or vanpools. Examples of park-and-ride facilities used with HOV lanes are shown in figure 6-21.

There are many benefits associated with the proper use of park-and-ride facilities, including the following: [16]

- Encouragement of use of high-occupancy travel to maximize the efficiency of the transportation system.
- Improvement in efficiency of transit system by providing high-density areas for transfers and by increasing ridership.
- Assistance with congestion management, through a reduction in the number of single-occupancy vehicles on the freeway.

Figure 6-21. Park-and-Ride Lots with HOV Lane. [9]

- Reduction in energy consumption and air pollution.

The following sections provide discussions on locating and designing park-and-ride facilities. The information in these sections was gathered from several sources, and the reader is encouraged to refer to these sources for further information.[16,17,18]

Location of Facilities

Choosing the optimum location for a park-and-ride facility involves investigating several factors. Factors that should be considered when selecting an appropriate location for HOV-related park-and-ride facilities include the following: [16]

- Locate facilities in advance of areas experiencing major traffic congestion.
- Locate facilities so that drivers have a direct route to the lot.
- Orient facilities to ensure good accessibility and visibility.
- Locate facilities at appropriate distances apart.
- Locate at transit stations.

Encourage cooperation among agencies involved in developing and operating the facilities.

The four general steps in choosing an optimum location for a park-and-ride facility include:

- Establishing site selection criteria.
- Identifying alternative sites.
- Evaluating alternative sites.
- Determining size of park-and-ride facility.

Establishment of Site Selection Criteria

During the site selection process, site selection criteria must be established. The criteria should be used both in the initial screening of potential sites and in the evaluation process. The American Association of State Highways and Public Transportation Officials (AASHTO) publication, *Guide for the Design of Park-and-Ride Facilities*, provides the following descriptions for the criteria to be considered:[17]

- **Facility Development Policy.** The park-and-ride facility development program may make use of publicly owned property, excess right of way, or property used with the permission of private owners, that may be used for other parking purposes. The policy establishes the guidelines for the relative importance of each type of facility within the program.

- **Site Availability.** The first step in the site selection process is the development of an inventory of potential sites.

- **Site Accessibility.** A site must be easily accessible to commuters and transit vehicles when transit service is anticipated. Park-and-ride facilities that are inconvenient for potential users will not, in most cases, be well utilized and so should be avoided.

- **Site Visibility.** Potential sites should be visible from their access roads. Visibility of park-and-ride facilities contribute to the recognition by passing motorists of their availability. Visibility of a park-and-ride site is a deterrent to vandalism and an asset to the security of vehicles.

- **Projected Demand.** Demand for park-and-ride space is based on analysis of individual travel corridors. The indicated demand provides a guideline for the number of potential spaces and estimated lot size that must be identified within each corridor.

- **Transit Service Availability.** Potential sites for park-and-ride facilities should be located along existing or potential transit routes. The potential for transit service should be considered even at those lots which are intended for carpool and van-pool users. If transit service is to be provided by the local transit agency, coordination is a very important element.

- **Accessibility to HOV Facilities.** Sites located adjacent to HOV lanes, HOV priority ramps or other priority facilities provide benefits to park-and-ride users. Coordination of the location of park-and-ride facility sites with HOV facility development can increase the usefulness, demand, and efficiency of both facilities.

- **Development and Operating Costs.** Since most park-and-ride lots do not collect fees, sites that can be developed economically are desirable. Potential development costs include related non-site costs such as added traffic signalization or intersection improvement costs. Shared use of a private facility, church parking lot, mall, etc., can be a factor in development and operating costs.

- **Available User Benefits.** Sites that provide users with the benefits of both travel time and cost savings are preferable to those that provide only a transfer opportunity.

- **Staged Construction Potential.** In many cases, it may be desirable to test demand analysis accuracy before committing funds for larger lots or more permanent construction. In these cases, it is desirable to have a site that can be developed in stages to reduce resource commitments until space requirements are verified. Staged construction potential is also desirable when projected land use development is expected to generate additional park-and-ride demand.

- **Development of Sites in Environmentally Sensitive Areas.** Special attention must be given to consideration of the placement of park-and-rides in areas determined to be especially environmentally sensitive.

Identification of Alternative Sites

Alternative sites for park-and-ride facilities can be identified using any one or a combination of the following techniques:[17,18]

- **Office Survey.** The goal is to identify those properties which would most readily be developed for parking and which have suitable access.
- **Field Observations.** Field reconnaissance along travel corridors is the preferred method of potential site identification.
- **Aerial Photography.** Aerial photographic mapping provides an ideal means of locating vacant land and private parking areas that can be easily related to travel patterns and corridor routes.
- **Local Contacts.** District highway engineers, local government officials, law enforcement agencies, transit representatives and other local groups can be used as sources to identify sites that are suitable for park-and-ride use.
- **Inventory Records.** Potential park-and-ride sites should be documented on an inventory record form.

Evaluation of Alternatives

Once alternative sites have been selected for the location of a park-and-ride facility, the next step is to evaluate the alternatives and choose the most appropriate location. Many transit agencies use some type of form or check list to evaluate alternative locations. The AASHTO *Guide* presents an evaluation form that includes criteria for establishing a priority rating system.[17] The primary categories of factors are classified below:

- Location Criteria.
- Site Considerations.
- Economic Considerations.
- Potential User Costs and Time.

The criteria used in the AASHTO approach will vary depending upon an agency's preference and needs.

Agencies may establish their own evaluation technique based on local practice and available resources; however, the procedure used should provide a comparative analysis of each site's potential that results in the most economical and efficient use of park-and-ride facility resources. During the site selection process, local officials should be given an opportunity to comment on sites proposed in their areas. [17]

Determining Size of Facility

Once an ideal location for the park-and-ride facility has been identified, the next step is to estimate the parking area required to serve the estimated demand. Factors affecting the required size of the lot include the following:[16,17,18]

- **Traffic Demand.** The major factor affecting the required size of the parking facility is the estimated average daily demand. It is recommended that the lot be designed to accommodate at least 10 percent more vehicles than the estimated average daily demand in order to ensure that adequate parking spaces are available on a typical day.[16,18]

- **Maximum Walking Distance.** Recommended maximum walking distances range from 120 to 300 m (400 to 1000 ft); however, maximum walking distance should not exceed 195 m (650 ft) whenever possible. Walking distance can be minimized by moving the transit station to a central location. Walking distances longer than 300 m (1000 ft) may require consideration of additional transit stations. [18]

- **Bus Service.** The frequency of buses using the park-and-ride facility affects the demand that can be accommodated. For example, as the headways between buses decrease, the number of passengers that can be serviced increases. The increase in transit capacity may increase demand, which will directly affect the required number of parking spaces.[18]

- **Rideshare Use.** Park-and-ride facilities used strictly for rideshare use (e.g., carpool and vanpool) will not have the same restrictions as those facilities accommodating bus service. For example, maximum walking distance will not be as big a factor because drivers will typically have a prearranged meeting location, rather than walking to a central waiting area.[16]

- **Access.** Inadequate capacity on nearby roadways and intersections may severely restrict the volume of traffic that can enter or leave the lot during a given time.[18]

- **Land Availability.** The size and shape of a lot may be restricted by land availability and/or site development costs.

Typical Designs

After an appropriate location is selected for the park-and-ride facility, the next step is to design the facility. There are a number of existing design standards that can be used as guidelines during the design process. Some of the better known documents are the previously mentioned FHWA and AASHTO reports.[17, 18]

Internal Lot Layout

Park-and-ride facilities that accommodate bus services encompass design elements for both parking lots and transit stations. Elements that need to be addressed in the design process are discussed below:[16]

Functional Area Design. The functional design of a park-and-ride facility should meet the requirements of user groups with different access modes. Examples of access modes that may need to be accommodated include the following:

- Long-term parking.
- Drop-off (or kiss-and-ride) areas.
- Handicapped parking.
- Bicycle racks.
- Pedestrian walkways.

In addition, facilities that allow parking for carpooling or vanpooling will need to provide space accordingly. An example of a typical layout for a park-and-ride facility is shown in figure 6-22.

Figure 6-22. Example of Park-and-Ride Layout. [9]

Internal Circulation. Park-and-ride lots should be designed to provide internal circulation to meet all modes of transportation and to minimize pedestrian/vehicle conflicts. Internal circulation should provide for safe and efficient movement of vehicles, buses, motorcycles, bicycles, and pedestrians.

Amenities. Amenities are elements that are considered to enhance the comfort and convenience of using a park-and-ride facility. The number and type of amenities provided will depend on a number of factors, such as: type of facility, anticipated use, local policies, and available funding. Typical amenities that may be considered for use at various park-and-ride facilities include the following:

- Public telephones.
- Trash receptacles.
- Newspaper vending machines.
- Other vending services.
- Transit information displays.
- Transit shelters.
- Seating/benches.
- Bicycle storage facilities.

Pavement and Drainage. Providing adequate pavement design and ensuring proper drainage are other objectives that must be addressed in the design stage. The pavement design will depend on the functional area that it will serve. Typical sources of design guidelines include the following:

- AASHTO standards.
- Local and state pavement specifications.
- Agency guidelines.

Landscaping. Using landscaping for park-and-ride facilities will enhance the appearance of the facility, which will in turn improve public acceptance and enhance the feeling of security. Landscaping should be designed to be compatible with the type of facility and the surrounding area. It should not interfere with sight distance, safe operation, or access to the facility. Guidance for landscaping is available in several publications, including publications by AASHTO and Federal Transit Administration (formerly UMTA).[19,20]

Lighting. Adequate lighting should be provided at park-and-ride facilities to promote safety and security. Factors that must be considered when designing for lighting include:

- Type of lighting.
- Mounting height.
- Spacing of luminaries.
- Intensity of lighting.

Recommendations for designing lighting at park-and-ride facilities are provided in the AASHTO *Guidelines*.[17]

Security. An important factor in ensuring the success of a park-and-ride facility is providing adequate security. Both personal safety and automobile security are important to users of the facility. Measures that are used to enhance safety and security include:

- Lighting.
- Fencing and gates.
- Security monitoring booths.
- Cameras and surveillance equipment.
- Signing.
- Ensuring adequate visibility from all parts of the facility.
- Quick removal of graffiti.

Environmental Considerations. Any effects that a park-and-ride facility will have on the environment should be considered in the design process. For example, effects on air quality can be addressed by minimizing the number of idling buses and vehicles. Factors besides air quality that should be considered include the following:

- Groundwater runoff and water quality.
- Noise impacts.
- Visual and traffic impacts.

Roadway Interface

Providing adequate access between a roadway and a park-and-ride facility is important to ensure efficient operation of the facility and to minimize the effects on surrounding roadways. Both the FHWA *Guidelines* [18] and the AASHTO *Guidelines*[17] provide design recommendations for interfacing the park-and-ride facility with the surrounding roadway. Design issues that are associated with roadway interface are discussed below.

General Access and Egress Considerations. Providing adequate access and egress for all modes of transportation should be considered when designing a park-and-ride facility. The location of entrances and exits can be controlled by a number of factors, including the following:

- Topography.
- Position relative to adjacent roadways.
- Types of local roadways.
- Types of traffic control.
- Connecting service provided by transit.

Access Points. Another factor that should be considered when determining the location of access points for park-and-ride lots is the effect on the surrounding transportation system. To determine the optimum location of access points, a traffic impact study should be conducted. The study should involve determining the current operating conditions on surrounding roadways and estimating the effects of different access points on existing traffic operations. Factors that may be investigated in the analysis include the following:

- Existing roadway capacity.
- Current traffic volumes.
- Normal projected growth.
- Projected growth due to park-and-ride lot.
- Impact of commercial development that may occur due to location of lot.

Access Roadways. On the basis of results from the traffic impact study, the capacity of the existing roadways should be analyzed to determine if they can handle the additional demand due to the park-and-ride facility. The analysis should investigate both current operating conditions and future (projected) conditions. The outcome of the analysis can be used to identify any needed improvements to the surrounding roadways.

Traffic Control Devices and Traffic Signals. The purpose of traffic control devices is to improve the safety and efficiency of traffic operations by providing guidance to drivers through the use of signs, signals, and roadway markings. The need for new traffic control devices, or for modifications to existing traffic control devices, should be identified in the traffic impact study. Guidance on the use of traffic control devices is found in the *MUTCD*.[13]

Handicapped Considerations

For park-and-ride facilities, handicapped considerations must be addressed during the design process for both the parking and bus loading area.

Parking

The AASHTO *Guidelines* contain standards for providing handicapped parking at park-and-ride facilities.[17] Parking-related factors that must be considered for handicapped provisions include capacity, location, design, and signing and marking.

Capacity. Standards for the minimum number of handicapped parking spaces given in the *Uniform Federal Accessibility Standards* are shown in table 6-7.

Location. Handicapped facilities are to be designed in accordance with State or local codes and should be provided at the nearest possible location to the bus loading zone.

Table 6-7. Accessability Standards. [21]

Total Parking Spaces	Required Minimum Number of Handicapped Accessible Spaces
1 to 25	1
26 to 50	2
51 to 75	3
76 to 100	4
101 to 150	5
151 to 200	6
201 to 300	7
301 to 400	8
401 to 500	9
501 to 1000	2%
Over 1000	20 plus 1 for each 100 over 1000

The facilities should be in accordance with the following considerations:

- Preferably no access roads or bus lanes should be crossed by handicapped patrons en route to the bus loading zone.
- The handicapped patron must never be forced to travel behind parked cars (in their circulation path).
- To facilitate the movement of physically handicapped patrons, wheelchair ramps must be provided.

Design. The designer should consider grading the handicapped parking stall so that the head of the stall is at the same level as the sidewalk and the rear of the stall is at the appropriate aisle grade. This will reduce the need for depressed curbs, keep the handicapped patron from crossing any type of storm drainage, and simplify construction of the handicapped parking area.

Signing and Marking. Appropriate signing and/or pavement markings should indicate the restricted use of the space for handicapped persons. Curbs to and from the bus loading area should be depressed for wheelchairs, as dictated by local standards.

Bus Loading Area

The Americans with Disabilities Act (ADA) of 1990 establishes guidelines for providing reasonable access to and use of buildings, facilities, and transportation. All new or renovated transit facilities must comply with the accessibility regulations in the ADA guidelines. Rules applying to transportation and transportation facilities are contained in *Transportation for People with Disabilities*.[22] The *Americans with Disabilities Act: Accessibility Guidelines for Buildings and Facilities, Transportation Facilities, and Transportation Vehicles* publication, hereafter referred to as the *Guidelines*, contains guidelines for meeting

ADA requirements for transit facilities.[23] Section 10 is titled "Transportation Facilities" and contains guidelines related to transit facilities. It also references portions of section 4 in the *Guidelines* that relate to transportation. A TCRP (Transit Cooperative Research Program) report discusses information in the *Guidelines* relevant to the design of bus stops.[(24)] Another TCRP report presents guidelines on the design and location of bus stops, and includes a summary of ADA issues.[(25)]

PARKING INCENTIVES

Implementing special parking policies can provide incentives for commuters to use high-occupancy modes of travel. For instance, adopting preferential parking for carpools and vanpools can increase the attractiveness of ridesharing. Examples of parking programs to induce commuters to use high occupancy vehicles include the following:[(26)]

- Preferential parking.
- Free or low-cost parking.
- Differential parking rates.

Preferential Parking

Preferential parking involves providing special parking spaces at the final destination for high-occupancy vehicles. The advantage of this strategy is that the utilization of existing parking facilities is increased without having to add additional parking spaces. Preferential parking strategies include the following:[(26)]

- Guaranteeing spaces for carpools and vanpools where parking is limited.
- Assigning closest and most convenient spaces to carpools and vanpools.
- Assigning specific garage spaces to carpools and vanpools.

Preferential parking strategies should also be considered as a part of new development. Using these strategies can reduce the parking requirements by designating parking spaces for high-occupancy vehicles during the planning process. This approach allows developers flexibility in meeting minimum parking requirements, while increasing ridesharing. [(26)]

Free/Low-Cost Parking

Free or low-cost parking is another strategy that can be implemented to encourage ridesharing. Using this strategy, carpools are allowed to park in designated areas for no cost or for a small monthly fee. Some of the parking programs that have been established around the United States allow carpools to purchase a permit for a small monthly fee. The permit allows these vehicles to park in designated spaces or to park at metered parking spaces without paying the standard fee. [(26)]

Differential Parking Rates

Another parking program to increase ridesharing involves charging commuters a flexible parking rate based on the number of occupants in a vehicle. The cost of parking decreases as the vehicle occupancy increases. An alternative is to maintain a constant parking rate and provide employers subsidies that vary according to vehicle occupancy. An example of this strategy that has been used by some private firms is shown in table 6-8.[(26)]

Benefits of Parking Incentives

Parking incentives have been shown to have a positive impact on the number of commuters that choose ridesharing alternatives. A study conducted in Washington, DC showed a 20 to 40 percent increase in commuters who chose to carpool when parking incentive programs were adopted. [(27)] A company in Boston, Massachusetts implemented a parking program in which the daily parking fee was

Table 6-8. Example of Differential Parking Rates. [22]

Vehicle Occupancy	Percentage of Parking Paid for by Employer
Single Occupant	0 %
Two-Person Carpool	50 %
Three-Person Carpool	100 %
Vanpool	100 %

dropped for vehicles with three or more occupants. The company reported that at least 34 percent of their employees shifted to carpools when this strategy was adopted.[26]

Most parking incentive programs are partially or wholly subsidized by employers for a number of reasons, including the following:[26]

- A sense of responsibility to promote energy conservation.
- A desire to reduce the costs of maintaining current parking arrangements.
- The need to eliminate new parking construction.
- Improvement in employee morale when employers take an active role in reducing transportation costs for employees.
- Possible favorable media coverage for participating employers when they are identified as contributing to energy conservation, air pollution control, and reduced traffic congestion.

Barriers to Implementing Parking Incentives

A critical barrier that typically impedes implementation of preferential parking strategies is public and business opposition. Opposition from these groups occurs for the following reasons:[26]

- Merchants, employers, and employees traditionally resist changes in the status quo.
- Merchants are leery of any changes in municipal parking supplies that they feel would reduce their competitive position with other retailers who offer free customer parking.
- Employers and employees often resist changes because parking is part of an overall benefits package.
- Some executives may fear that they will lose their parking privileges by adopting this type of strategy.

There have been some factors, however, that have influenced officials in some cities to call for policies that would enhance the coordination between traffic demand management and parking incentives. Factors to be considered include the following:

- Auto ownership continues to increase. Ownership has increased at a rate of 2.5 times the population growth rate over the past few years.

- Structure parking is becoming prohibitively expensive.

- Metropolitan freeway construction is extremely expensive and is widely perceived to be environmentally disruptive.

EMERGING TECHNOLOGIES

Enforcement

The Texas Transportation Institute (TTI), in a research study sponsored by the Dallas Area Rapid Transit (DART), Federal Highway Administration (FHWA), Federal Transit Administration (FTA), and Texas Department of Transportation (TxDOT), is investigating the use of advanced technologies in HOV lane enforcement. The study is aimed at identifying technologies to improve the safety and cost-effectiveness of HOV lane enforcement. The study's objective is to identify the most promising technology and perform a 6-month operational test on the East R. L. Thornton (I-30) Contraflow HOV lane in Dallas, Texas. The results of the operational test will help DART improve enforcement procedures in HOV lanes in Dallas.

The enforcement system will perform the following basic functions: [28]

- Collect and transmit video images of vehicle license plates and vehicle compartments for all HOV lane users to a remote computer workstation.

- Perform automatic license plate character recognition on the license plate video image.

- Synchronize captured video images of vehicle occupants with license plate numbers.

- Search a license plate database containing vehicle occupancy histories and, based upon failure to meet set criteria, display the vehicle license plate number and vehicle compartment images on a computer monitor for review and enforcement purposes.

After the equipment is procured and installed, an operational test will follow to evaluate and refine the enforcement procedures. The operational test is expected to be concluded by August 1997.

Movable Barrier

The movable concrete barrier system consists of a barrier transfer vehicle and a movable concrete barrier (see figure 6-23). The main advantage of the barrier is its ability to provide a solid, physical separation between opposing flows of vehicles. The movable barrier consists of 0.9 m (3 ft) concrete segments jointed together by pins. A specially designed conveyor system on the self-propelled transport and transfer machine (TTM) is used to shift the barrier laterally across the roadway (see figure 6-24). The distance of the shift can vary from 1.2 to 6.7 m (4 to 22 ft). The T-shaped barrier top is engaged by conveyor wheels on the TTM. The barrier is then lifted several inches off the ground, moved sidewinder fashion through an elongated S-curve, and repositioned to form a new lane. Barriers can be moved at up to 8 km/h (5 mi/h), depending on the circumstances.[29]

The use of the movable barrier to create the HOV lane on the East R. L. Thornton (RLT) Freeway in Dallas began in September 1991. The movable barrier shifts the barrier approximately 6.7 m (22 ft) laterally to

Figure 6-23. Movable Barrier. [9]

Figure 6-24. Movable Barrier Used in Dallas. [9]

create an extra travel lane for the peak direction of flow. The implementation of this HOV lane was accomplished by narrowing freeway lane widths to 3.4 m (11 ft) and reducing the inside shoulder of the freeway in some locations (see figure 6-25). The contraflow lane is 8.4 km (5.2 mi) long. The cost to construct this contraflow lane (in 1995 dollars) was $15.4 million. In December 1995, the East RLT HOV lane served 13,572 daily person trips.[26]

The second contraflow HOV lane to use a movable barrier opened in November 1995 on the I-93 Southeast Expressway in the Boston metropolitan area. Like the project in Dallas, the I-93 contraflow HOV lane is created by moving a concrete barrier from the median across one traffic lane to create an additional HOV lane in the peak direction of travel. After six months of operation, the HOV lane, or *zipper* lane as local commuters call it, has met the operational goals for the initial phase of the project. In 1996, the lane carried over 14,400 people each weekday. Concerns expressed about operation during winter weather were dispelled when the lane was opened 99 percent of scheduled times during the snowiest winter in Boston's history (250 plus cm (100 plus in).[29]

6.4 LESSONS LEARNED

PLANNING

A planning process that yields information on the best possible HOV candidates should be undertaken to ensure an efficient and effective HOV facility. This can aid in determining the type of HOV facility needed and the proper vehicle eligibility requirements. Operational considerations such as operating periods, eligibility, active traffic management, incident response, and enforcement should be addressed during the planning process. When operational issues are not considered, the end result can be an HOV facility that is mismanaged, vulnerable to long periods of nonuse when incidents occur, and difficult to enforce.[5]

Fuhs developed a generic process for evaluating HOV alternatives. [5] The four stages are as follows:

- **Stage 1: Conceptual Viability.** The first of the four stages of HOV development is an evaluation of HOV conceptual viability, accomplished by applying a list of criteria to the candidate corridor. If the corridor fails to meet these criteria, it should be excluded from further consideration, or efforts should be undertaken to better understand what may be needed for the criteria to be met.

- **Stage 2: Alternative Development.** The second stage involves a more qualitative and quantitative assessment of the merits of the candidate corridor and an identification of the specific types of HOV designs and operational elements that are applicable and feasible. There is less likelihood that a candidate corridor will be excluded at this stage; however, a number of design and operation alternatives may be created at this stage that warrant further study. If this is evident, follow-on studies may occur here to better assess the relative merits of each.

- **Stage 3: Development of Recommended Alternative(s).** The third stage involves development of one or more recommended alternative(s). This stage focuses on specific design and operation issues that deserve attention. Activities include the following:

    - Selected elements of preliminary engineering.

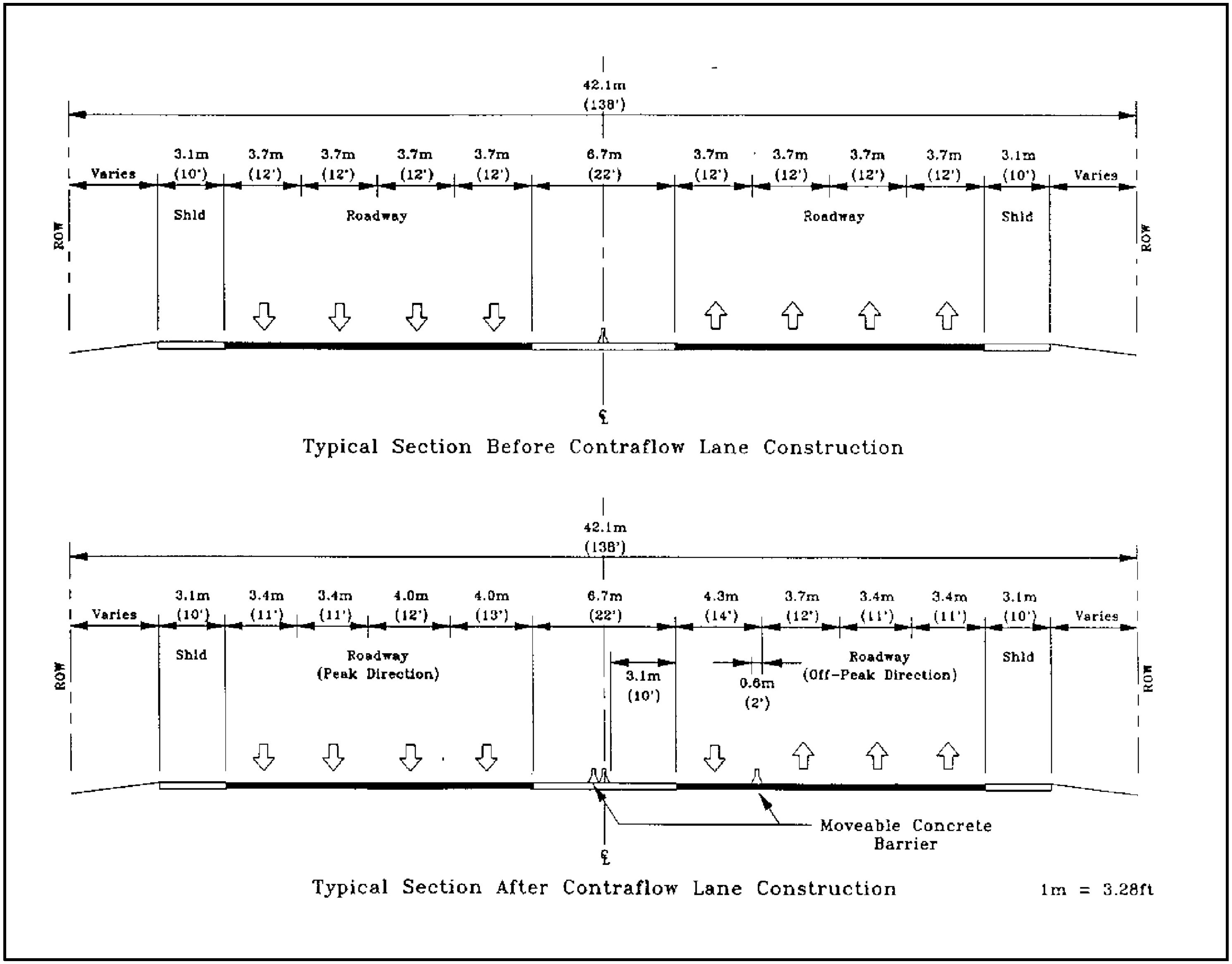


Figure 6-25. Typical Sections, Before and After East RLT Contraflow Lane Construction.[26]

- Checks for constructibility and implementation staging.
- Support facilities (park-and-ride and/or park-and-pool lots, and on- and off-line bus facilities, etc.).
- Identification of supporting programs like ridesharing.
- Implementation phasing.
- Cost estimating and cash flow analyses.
- Other corridor-specific issues.

Products from this third stage include an operation plan and a geometric design plan.

- **Stage 4: Plan Adoption.** The fourth and final stage is formal adoption of the local preferred HOV plan. The results of the HOV planning study are officially sanctioned by respective boards, commissions, or other official bodies, and an implementation process is defined. The adopted HOV plan may be a stand-alone approach or may be one of a number of other capacity alternatives (highway or transit) that are subjected to alternative and environmental analysis before being eligible for design and construction.

Public and Political Support and Consensus Building

HOV concepts are often not understood by the public, politicians, or media. Within the scope of the planning study, a multiagency review group (also called an advisory committee or steering committee) should be formed. Their role includes the following:

- Technical and policy guidance
- Concurrence powers at major decision points.
- Coordination and liaison with others in the respective agencies.
- Outreach to greater public participation efforts as needed.

HOV projects are particularly in need of this type of oversight, where an ongoing commitment is needed among a number of agencies to effectively plan, implement, operate, enforce, maintain, and modify the HOV project as necessary to ensure continued viability. The composition of the review group may vary during the planning and implementation process, but at a minimum, representatives from affected local agencies, police, the state DOT, and the FHWA should usually be involved. If a project is adopted for implementation, this group should continue to function through the design phase, and some semblance of the group should be named to provide operation and maintenance overview of the HOV facility once it is opened.(5)

Apart from the multiagency review group, focus groups composed of local civic associations, special interest groups, politicians, the media, and others may be necessary to bring public participation into the planning process. This process should be highly structured to keep issues focused. Appropriate in many areas will be the need for some public awareness outreach to market the HOV concept. There are four steps to an effective public education program:(5)

- Information should be disseminated three to four months prior to the opening of the project to prepare the public for the new facility and its regulations.

- During the first few weeks of project operation, there should be an intense public relations effort until users are familiar with the HOV facility and its operation.

- As soon as data on project use are available, they should be presented to the public to disseminate information about the positive impacts from the project.

- The public education program should be continued, as needed, to reinforce an understanding of concept objectives and the role of enforcement.

An important lesson that has been learned from project failures to date is that the public must be involved and must be able to understand and appreciate the role that HOV systems can serve. To this end, any HOV planning process will necessarily need to be an information, awareness, and education process as well.

Public Involvement

Traditional methods of public notification and community relations are important to gaining public acceptance of changes to transportation services. The public interest, however, has progressed to a desire to become directly involved in the initial and ongoing decisions about service and design. Public involvement is not public relations. Public relations strategies attempt to position an issue, project, or plan in the best possible light for decision-makers and the public. Frequently the objective is to gain public acceptance of a prior decision. Public involvement, on the other hand, involves the public in the shaping of policy and project decisions that affect a community. Public involvement is best initiated before project alternatives are developed or decisions made. Public involvement can be loosely divided into four components—data gathering, public and private communications, promotion, and evaluation.(2)

- Data Gathering.
  - Literature Search.
  - Surveys.
  - Focus Groups.
  - Focused Interviews.
- Public and Private Communications.
  - Kick-Off Briefing.
  - Community/Jurisdiction/Elected Official Briefings.
  - Public Meetings, Hearings, Open Houses, Workshops.
- Promotion (Heightening General and Targeted Awareness).
  - Media Relations.
  - Newsletters.
  - Speakers Bureau/Public Forums.
  - Advertising and Public Service Announcements.
  - Special Events and Ceremonies.
  - Customer Service Representatives and Other Staff.
- Evaluation.
  - Survey.
  - Focus Groups.

- Focused Interviews.
- Public/Private Partnerships.
- Sponsorships: Corporate & Media.

System Approach to HOV Planning

Most HOV projects have been implemented on a corridor basis. As such, *corridor planning* has been pursued with focused evaluation on the specific needs and travel characteristics of the corridor in mind. As additional corridors have been addressed in a region, there has been a recognition of the need for *regionwide system planning*, in which a broader perspective of HOV applications for a metropolitan area is studied. There have been few cases where regional system planning occurred prior to the study of a particular corridor. Pursuing a regionwide approach assumes a much higher level of commitment to the HOV concept as a valid regionwide option.

Regionwide planning recognizes the relationships among system elements, particularly in staging system implementation to maximize early benefits. Regionwide issues may influence operation polices in which the same hours of operation or rules regarding eligibility are uniformly established for all projects in a given area. This policy of operation consistency has been adopted for Orange County, California, while the Seattle and Houston areas have policies allowing operation policies to be tailored to the unique attributes of each corridor. Both policy approaches can be locally popular and successful.(5)

Possible Pitfalls in Implementation

The following are typical issues to be aware of and to avoid in the implementation process:(5)

- **Policies and Procedures***:* Involved agencies are often unaware of the strings attached to funding, review, and approval steps, and the procedures required for project implementation. Involved agencies should become familiar early on with the rules and policies associated with funding, programming, and implementing projects. This is particularly important when more than one agency is actively involved in the process. FTA and FHWA guidelines are not always in agreement. State policies and procedures may not be familiar to local agencies assisting the State in various activities.

- **Involvement**: In trying to accelerate the effort, some of the agencies that should be involved are overlooked.

  Keep all appropriate agencies involved in decisions being made. This will keep the project properly focused and on schedule.

- **Commitment**: One agency pursues the project without additional external, and sometimes internal, support.

  A dedicated commitment is needed from all the respective parties before proceeding with a project. This provides a broader base of support for sustaining the project.

- **Taking Unnecessary Risks**: In an attempt to achieve faster results, authorization is given to proceed on future activities before all reviews and approvals have been acquired from prior actions.

  Risk management is involved in any implementation process. If such risk is to be taken, it should be based on a general consensus from the project team with an understanding of the possible downside impacts.

- **Changing Course**: A prior approval or commitment is rescinded, for any of a number of reasons.

  Inevitably, as any project progresses into greater and greater detail of development, there can be justification to re-explore a prior matter that was thought resolved. In such instances, the project manager can be effective in bringing together the affected parties to reach a renewed understanding and, if necessary, to change the course or scope of the project. Recurring problems of this sort may require resolution at higher levels in the organization, providing another reason why a top-down commitment to a project is essential before undertaking implementation.

- **Scope, Budget, and Schedule**: An early effort should be undertaken to understand any change in scope, schedule, and budget and to obtain a resolution that rebalances these variables. Performance and delivery expectations should be based on a realistic understanding of the project requirements. The risks of fast-tracking a schedule, for example, should be defined and understood. Again, a single project manager can be the focal point for this understanding.

Tables 6-9 to 6-10 list characteristics of successful HOV facility implementations and potential pitfalls, respectively.

Development Concerns for Park-and-Ride Facilities

There are many factors that must be considered when implementing a park-and-ride program. These factors are discussed below.

Program Planning

Program planning involves developing the operating plan that defines specific program requirements. These planning requirements are discussed below:

- **Site Development Policies.** Once it has been determined that park-and-ride facilities will accompany specific HOV lanes, the first step is to establish site development policies. These policies will provide guidance in developing the facilities. Typical policies that need to be addressed include the following:

  - Stage construction guidelines.
  - Maximum or minimum size lots.
  - Extent of amenities (e.g., telephones, lighting, etc.) to be provided.
  - Transit service guidelines.
  - Joint accommodation of carpools and vanpools with transit users.

- **Inventory of Potential Sites.** The next step is to identify potential sites. This can be accomplished by a number of means, including the following:

Table 6-9. Successful Characteristics of HOV Facility Implementation. [(2)]

☞ Clear set of objectives and measures of success
☞ Development of the HOV lane as an additional lane
☞ Existing congestion in corridor (able to save 1/minute/mile & 5 to 8 minutes total)
☞ Projections for continued increase in demand
☞ Enforcement commitment/collaborative working relationships with enforcement agencies/courts along the corridor
☞ Reason to believe you can get support from both agencies and public
☞ Reason to believe you can provide a lane that can be safely operated and enforced
♥ Policies and programs supporting transit use
♥ Rideshare program in corridor
♥ Successful HOV facilities already in operation in same corridor or adjacent corridors
♥ High existing volume of 2+ HOV's (700 or more vehicles per hour)
♥ Traffic system management program already in place along the corridor
♥ High level of convenient transit service along the corridor (local/express/Park & Ride routes)
♥ Commute trip reduction legislation
♥ Existing communication network with employers along the corridor
♥ Collaborative working relationships with environmental agencies/groups along the corridor
♥ Collaborative working relationships with neighborhood/community groups along the corridor
♥ Collaborative working relationships with local jurisdictions/transit agencies/DOT along the corridor
♥ Commitment to evaluation to accurately show benefits/disbenefits
♥ Origin-destination pattern that can benefit from the HOV lane

Legend
☞= Essential Characteristic
♥= Desirable Characteristic

- ▸ Aerial photographs.
- ▸ Excess property lists.
- ▸ Field reconnaissance.

- **Facility Implementation Priority Rankings.** Once potential sites are identified, a list of the sites is prepared for use in defining the short-term and long-term programs. The next step is to establish a methodology to allocate available funding and to address the most critical needs on a priority basis.

- **Short-Term and Long-Term Site Development Programs.** Short-term and long-term site development programs are established to provide for planning, design, construction, funding, scheduling, and resource allocation.

- **Transit System Interface.** The location of park-and-ride lots should be coordinated with existing and proposed transit routes to maximize the benefit of these facilities.

Table 6-10. Potential Pitfalls to Successful HOV Facility Implementation. [2]

• Converting existing general purpose lane to HOV lane, may result in negative impacts (increased accidents, increased travel time, etc.) in general purpose lanes or protest by the public • High accident rate along the corridor that will not be improved by HOV lane • Little support from enforcement authorities (State Police/Patrol, municipal judges/magistrates) • Low existing volume of HOV • Poor working relationships with local media • Poor working relationships with neighborhood/community groups along the corridor • Poor working relationships with elected officials (especially critical during election years) ➢ Changing lane designation from general purpose to HOV during lane construction (example: begin construction as general purpose, change designation during construction phase to HOV) ➢ Low level of transit service ➢ Lack of transit funding ➢ No/low level of support facilities ➢ No incident management program in place ➢ No/inadequate ride matching services ➢ Poor pavement maintenance of existing facility that would not be helped by HOV lane construction ***Legend*** •= Potential Fatal Flaw ➢= Possible Problem

- **Roadway Interface.** The development of park-and-ride lots should also be coordinated with HOV lanes to provide for proper design of access routes and entrances. The objective should be to provide access to HOV lanes in a way that will maximize travel time savings for the users of the facility.

Design Requirements

Both transit planners and traffic engineers should be involved during the design process to ensure proper operating conditions for buses and cars. Standard design manuals for park-and-ride facilities are available and should be used to control design quality.[16,17,18] A following section titled *Typical Designs* provides a summary of some existing design guidelines.

Operation and Maintenance

It is very important that operation and maintenance issues be addressed during the development process. For example, it is important to ensure that adequate funding is available for the operation and maintenance of a facility. Also, the agencies and groups responsible for the operation and maintenance of the facility should be identified early in the development process:

- **Operation.** The successful operation of park-and-ride facilities will require close cooperation among local transit agencies, the community, and the State DOT. The operation of a park-and-ride facility involves a number of elements, including the following:[18]

  - Parking fee structures.
  - Frequency of transit service.
  - Fares for transit service.
  - Carpool use.
  - Providing security.

- **Maintenance.** Providing proper maintenance of a facility also has a significant impact on the success of a park-and-ride program. Ensuring that the facility is clean, attractive, and well maintained will have a positive impact onusers. In developing a comprehensive maintenance program, several factors must be considered:[16]

  - Periodic inspection.
  - Pavement repair.
  - Shelter or station repair.
  - Traffic control devices (e.g., signs and pavement markings).
  - Lighting.
  - Mowing.
  - Sweeping and cleaning.
  - Trash removal.
  - Landscaping.
  - Site furnishings.
  - Snow and ice maintenance.
  - Security/gates.

Program Marketing

The objective of a marketing program is to inform motorists about the park-and-ride facility and available transit services. It is important to develop a marketing program during the implementation of a new park-and-ride facility; however, ongoing marketing efforts are also important for the continued promotion of the facility. Two important needs that should be addressed when developing a marketing campaign are as follows:[16]

- Identify target audience.
- Determine effective mechanism for communicating desired information.

Examples of actual marketing techniques include the following:[16]

- Direct mail.
- Radio.
- Television.
- Newspaper.
- Billboards.
- Roadside signs.
- Lot location maps, transit maps, and transit schedules.
- Employer-focused efforts.

For further information on the marketing of HOV systems, the reader is referred to the

High Occupancy Vehicle (HOV) Lane Marketing Manual.[30]

DESIGN/CONSTRUCTION

The development of HOV facilities within freeway corridors is typically a retrofit process. Not all desirable design standards are likely to be obtainable. Some compromise in design requirements will probably be needed, and the elements of compromise will differ from one location to another. Tradeoffs need to be considered on a case-by-case basis, according to an agreed-upon understanding of what design treatments are acceptable to the appropriate reviewing agencies. Therefore, HOV practitioners recognize that the typical recommended designs provided in any of the currently available design resources must be considered as *guidelines* and not *standards*. The guidelines are of two types, *desirable* and *reduced*.

- *Desirable* design guidelines are those that should be considered in the concept development of any new or substantially reconstructed freeway corridor or HOV guideway in separate right-of-way. Desirable guidelines are generally recognized as reflecting a permanent facility treatment with the same commensurate design as that which would be applied to a new freeway with full design standards. HOV projects constructed with these dimensions have had significant costs and have been accompanied by substantial freeway reconstruction as well.

- *Reduced* design guidelines are those that may be considered for retrofit projects on a case-by-case basis, where space or cost considerations might otherwise make application of the HOV treatment environmentally infeasible or cost prohibitive. Reduced designs often reflect restriping or otherwise modifying the existing freeway to achieve an HOV operation that may be termed "interim," with a longer-range intent for meeting desirable guidelines. The reduced dimensions have also been used in short sections of projects otherwise meeting desirable standards, where significant cost would have been incurred to provide the desirable widths.

Tradeoffs in Retrofitting Cross Sections

The process of retrofitting HOV facilities onto existing freeways requires design compromises. Often, bridge columns, narrow structures, limited right-of-way, and other isolated constraints are encountered which make adherence to desirable or even reduced criteria difficult without some commensurate reduction in the overall cross section of the freeway. Design compromises should be thoroughly investigated before an HOV facility is implemented. The key concerns relevant to this issue appear to be cost effectiveness of the remedy and length of the design exception required. If reductions in typical guideway standards are necessitated, general practice indicates that the sequence of tradeoffs presented in table 6-11 should be considered when making these determinations.[5]

Impacts of Ingress/Egress on Adjacent Freeway and Arterial System

HOV ingress/egress designs have evolved through experience, and much has been learned from various applications. Following are a few general guidelines:[5]

- Where possible, the same geometric criteria should be applied as would be used for a freeway ramp, including locally recognized entrance and exit design standards.

Table 6-11. Tradeoffs in Reducing Cross Section Elements.[5]

Compromise Sequence	Cross Section Element		
	For Reversible-Flow HOV Facilities	**For Two-Way Barrier-Separated HOV Facilities**	**For Buffer-Separated HOV Facilities**
First	Reduce single-lane HOV envelope to no less than 6 m (20 ft), or two-lane envelope to no less than 8.5 m (28 ft).	Reduce left HOV lane lateral clearance to no less than 0.6 m (2 ft).	Reduce left HOV lane lateral clearance to no less than 0.6 m (2 ft).
Second	Reduce freeway left lateral clearance to no less than 0.6 m (2 ft).	Reduce right HOV lane lateral clearance to no less than 2.4 m (8 ft).	Reduce freeway right lateral clearance (shoulder) from 3.1 m (10 ft) to no less than 2.4 m (8 ft).
Third	Reduce freeway right lateral clearance (shoulder) from 3.1 m (10 ft) to no less than 2.4 m (8 ft).	Reduce freeway left lateral clearance to no less than 0.6 m (2 ft).	Reduce buffer separation to no less than 0.3 m (1 ft).
Fourth	Reduce HOV lane width to no less than 3.4 m (11 ft) (some agencies prefer reversing fourth and fifth steps when buses are projected to use the HOV facility).	Reduce freeway right lateral clearance (shoulder) from 3.1 m (10 ft) to no less than 2.4 m (8 ft).	Reduce HOV lane width to no less than 3.4 m (11 ft) (some agencies prefer reversing fourth and fifth steps when buses are projected to use the HOV facility).
Fifth	Reduce selected mixed-flow lane widths to no less than 3.4 m (11 ft) (leave at least one 3.7-m [12-ft] outside lane for trucks).	Reduce HOV lane width to no less than 3.4 m (11 ft) (some agencies prefer reversing fifth and sixth steps when buses are projected to use the HOV facility).	Reduce selected mixed-flow lane widths to no less than 3.4 m (11 ft) (leave at least one 3.7-m [12-ft] outside lane for trucks).
Sixth	Reduce freeway right lateral clearance shoulder from 2.4 m (8 ft) to no less than 1.2 m (4 ft).	Reduce selected mixed-flow lane widths to no less than 3.4 m (11 ft). Leave at least one 3.7-m (12-ft) outside lane for trucks.	Reduce freeway right lateral clearance shoulder from 2.4 m (8 ft) to no less than 1.2 m (4 ft).
Seventh	Convert barrier shape at columns to a vertical face.	Reduce freeway right lateral clearance shoulder from 2.4 m (8 ft) to no less than 1.2 m (4 ft).	Transition barrier shape at columns to a vertical face or remove buffer separation between HOV and mixed-flow lanes.
Eighth		Convert barrier shape at columns to a vertical face.	

Adapted from Caltrans *HOV Guidelines*, as reported in the reference.

- The typical volumes using HOV access ramps are less than for commensurate freeway ramps. HOV volumes accessing a local street seldom overwhelm a signalized intersection. Average peak-hour ramp demand at an intersecting street probably will not exceed 300 to 500 vehicles per hour.

- Sight distance is particularly critical due to the proximity of barriers to ramp lane alignments. Lateral clearances are often no further than 0.6 m (2 ft) from the edge of the travel lane to barrier. Where practical, removal of barrier-mounted glare screens or slight adjustments in striping alignment may be necessary within the ramp envelope to accommodate the proper design speed.

- The location of ingress/egress facilities is influenced by a number of factors. For example, direct access ramps to/from local streets should be made with candidate streets that currently do not have freeway access, so as to better distribute demand and prevent overloading existing intersections. For at-grade access to the adjacent freeway lanes, designated outlets should be strategically positioned so as to minimize erratic weaving to reach nearby freeway exits.

- Left- or right-hand exits from a one-lane HOV facility are equally valid and equally safe. The standard “right hand only” rule for entrance and exit ramps should not apply to HOV facilities.

- Where possible, entering and exiting movements should be shared on the same structure or space envelope between retaining walls to reduce cost.

- Adequate advance signing should be provided, and pavement markings should emphasize the mainline (possibly through use of skip stripe markings across the diverging exit ramp).

- Safety lighting should be applied for all ingress/egress locations, using the same warrants as are applied for metropolitan freeway entrance and exit ramps.

- Where possible, provision for entrance ramp metering and/or enforcement should be considered (these are project-specific considerations based on a number of local issues and input from enforcement agents).

Signing Guidelines

Signing guidelines for HOV facilities should be no different than for any other high-speed highway application. Regional consistency should be considered when arraying periodic information regarding rules, policies, and operating procedures. The pitfalls commonly evidenced on projects include the following: [5]

- Lack of adherence to MUTCD color standards.

- Lack of diamond symbol exhibited on signs.

- Confusing regulatory sign information.

- Sign lettering too small to be read at the posted speed.

- HOV guide signs that can be read and misconstrued by mixed-flow drivers.

- Signs that have not been adequately upgraded to reflect the most current operating rules.

The following are general recommendations for handling these shortcomings and applying the MUTCD chapters:[5]

- The standard sign for HOV regulatory and guide signing is black-on-white, with a white diamond symbol on black background in the upper left corner. The diamond symbol should appear on all signs related to HOV user and nonuser communication (regulations and guidance).

- The size of the sign should be commensurate with the design speed, using the same relationship in letter size as is required for any other highway signing.

- Signs should be considered on the approaches to all HOV ingress and egress locations and at the ingress/egress locations themselves. It may be necessary to mount such signs over the lane to provide proper sizing. Guide signing for HOV users is necessary on HOV facilities that have designated ingress/egress locations.

- Regulatory signs related to lane restrictions should be mounted over the lane at regular intervals.

- Regulatory signs located in advance of a preferential lane should be mounted on the appropriate side of the approach roadway.

- If dynamic signing is used, the diamond symbol should be applied on or above the variable sign in the upper left corner.

- Regulatory signing should periodically clarify user eligibility, hours of operation, directionality (if appropriate) and other restrictions on the operation along the length of the facility. Regulatory information should be repeated along nonbarrier-separated facilities at 0.8 to 1.6 km (0.5 to 1.0 mi) intervals. Regulatory information for barrier-separated facilities can be displayed at entrances and exits only.

- Carpools and vanpools should be defined in terms of "PERSON" numbers. (Sample message: Buses and 2+ *Person* HOVs only.)

- Where lateral clearance is limited, as for a ground-mounted sign affixed to the median barrier, the sign panel may have to be skewed as much as 30 degrees to allow for an increase in panel length.

- All signing should be reevaluated whenever operation policies change. Signs should be changed in accordance with the revised policies and not be cluttered with amended information that confuses or contradicts the primary message or information being communicated.

- Where guide signing for similar destinations can potentially be seen by both HOV users and nonusers, the HOV message should be reinforced with the diamond symbol. All guide signs in the area of confusion should be mounted over the appropriate roadways.

Pavement Marking Guidelines

There is generally more diversity in pavement markings, and this is due to wide variation in locally accepted standards and uncertainty over proper pavement marking treatments. Following are general recommendations for interpreting and applying guidelines in the MUTCD: [5]

- Reserve the use of the diamond symbol on signs and pavement markings for

HOV treatments. Although the MUTCD recommends this symbol for bicycle lanes, and for commercial or other purposes not related to HOV, practitioners now concur with restricting the diamond symbol to HOV applications. The placement of the diamond on the pavement should be frequent enough to communicate the restrictive nature of the lane. Along higher-speed freeway facilities, the interval should be from 153 to 305 m (500 to 1,000 ft).

- The colors of pavement markings should, as a general rule, be in compliance with the MUTCD. White is usually applied to communicate a concurrent-flow condition; yellow is applied to communicate a potential for adjacent oncoming vehicles. Solid lines denote that crossing of the marking is not permitted. There are local exceptions.

- For a barrier-separated two-way configuration, a solid white stripe should delineate a right shoulder and a solid white or yellow stripe delineate the left edge of the travel lane. For buffer-separated lanes, the buffer should always be delineated with solid stripes, preferably white, if continuous access is not allowed. Some buffer-separated projects use a combination of white and yellow. Nonseparated lanes that allow continuous ingress/egress and become mixed-flow lanes during at least part of the day should apply standard freeway lane delineation. Contraflow lanes should apply a separation stripe that is either a single or double yellow dashed stripe . Queue bypasses should apply the same pavement markings as are routinely applied along ramps. The stop bars for meters should be highly visible and quite large (typically 20 to 30 cm [8 to 12 in] wide).

- Use of dashed (skip-stripe) markings across an exit ramp should be applied where there is possible confusion over the orientation of the mainline HOV facility. This is more likely where HOV ramps enter and exit from the left.

- Cross hatching of buffers of gore areas helps direct traffic, but is difficult to maintain. Some projects include cross hatching initially; however, they are not maintained. Drivers' experience and knowledge of the HOV facility provide guidance after the markings fade.

- Avoid use of raised reflectorized delineators of buttons in conjunction with pavement markings wherever motorcycles are allowed as eligible users. Consult with local police if motorcycle enforcement patrols are being considered.

OPERATIONS

Surveillance, Communication, and Control

An HOV facility operating without a surveillance, communication, and control (SC&C) system must rely on area traffic bulletins, police reports, or bus operator communications to locate and remove incidents. This approach can be acceptable and has proven adequate in most HOV applications. With the SC&C system, loop detectors and CCTV provide operators with information on the real-time operating status. An incident can be located in seconds. It is this reduction of time in locating a disabled vehicle, and its subsequent prompt removal, that provide travel time savings to the HOV facility users in the event of an incident. And, like any freeway operation, the greater the traffic volumes, the greater the delay that is associated with the increasing number of incidents.[10]

For the HOV facility to maintain a higher quality of service at all times, electronic surveillance and communication tools can help operators respond to an incident that disrupts flow. Applying technology to both the HOV facility and the mixed-flow facility in a common corridor may bring incremental benefits and economies of scale. Either consideration or expanded use of surveillance and communication techniques is prudent in the design phase, even if the only steps taken are to allow for easier adoption of this technology at a later date. Typical treatments in the roadway design that complement future installation include the following: [5]

- Inclusion of conduits adjacent to or under the outside shoulders (normally two, 7.6-cm (3-in) conduits are adequate). Placement of conduits inside barrier alignments is not recommended due to the difficulty in accessing the conduits.
- Inclusion of conduit valve openings within any longitudinal box beam structures and abutments.
- Placement of additional induction loops in Portland cement concrete pavement at 0.4 to 0.8 km (¼ to ½ mi) intervals. Up to three loops in a series should be applied, even if all are not ultimately used.

Incident Response

Once an incident is detected, a key to minimizing delay to HOVs is the speed with which the incident is cleared. Effective incident response must include service equipment and facilities that, upon detection and location of an incident, allow for the rapid removal of that incident.[10]

One important consideration in incident management on HOV facilities is the cooperation of the agencies responsible for providing the needed response. Often more than one department of an agency, or more than one agency, is involved. Since the priorities within each agency may be different, it is sometimes difficult to achieve the full cooperation of all parties. Matters involving multiple jurisdictions can also complicate the management process. To overcome these differences, it may be necessary to create an incident management team composed of representatives of the major operating agencies and governmental entities. At a minimum, the incident management team should coordinate incident response with existing groups or freeway incident management personnel, if any.[10]

An additional resource in incident response is the media. The dissemination of real-time traffic information by a central control facility to radio and/or television stations allows all citizens, especially commuters, to receive up-to-the-minute traffic information.[10]

Enforcement Strategies

Enforcement strategies are influenced by the compliance goal for a facility, accepted local practices of the enforcement agencies, and available staffing and resources. An acceptable violation rate varies from one type of priority treatment to another. In general, violation rates should be capable of being managed to no more than 10 to 20 percent of the observed traffic stream in the HOV facility.[5] Four primary enforcement strategies are being used on HOV facilities:[31]

- **Routine enforcement** activities are those activities which are randomly conducted in concert with normal police monitoring duties. Routine enforcement could be appropriate if the violation rate experienced is considered acceptable by the project management.

- **Special enforcement** is characterized by continuing, systematic staff allocations and enforcement tactics specifically dedicated to enforce HOV violation rules. It is used when routine enforcement cannot effectively address HOV needs without sacrificing other enforcement duties.

- **Selective enforcement** combines both routine and special approaches. Although most enforcement is routine, special tactics are applied periodically to specific problem areas where violations have been observed.

- **Self enforcement** means having motorists and HOV users police themselves, identifying noncompliance with the HOV facility and taking voluntary actions to report violators.

Other Users

Other users that are eligible (or considered for eligibility) for some HOV facilities include the following:[5]

- **Motorcycles.** Inclusion of motorcycles has been promoted by some as an effective and safe way of segregating these vehicles from the mixed-flow traffic stream. The 1982 Surface Transportation Act passed by Congress leaves the decision, in effect, to local authorities. The act specifically includes motorcycles as eligible to use HOV facilities constructed with federal aid funds, unless the responsible operating agency(s) take measures to have motorcycles prohibited for safety reasons. There does not appear to be any nationwide evidence to substantiate reports of positive or negative impacts associated with motorcycles. Inclusion of motorcycles as eligible users seems to be a local issue that has been effectively addressed at the local/state level.

- **Commercial vehicles.** The role of commercial trucks in moving goods to market has expanded significantly. Reducing commercial vehicle transportation costs can mean a higher domestic standard of living and a more competitive position for the U.S. in the world marketplace. For these reasons it is becoming increasingly viable to think of trucks as priority vehicles. A policy that includes large commercial vehicles (e.g., any vehicle with more than two axles) in HOV facilities has been proposed over and over, particularly by the general commuting public and politicians, as a means of remedying conflicts in the mixed-flow traffic stream. With greater focus being given to restricting trucking operations on metropolitan freeways or during peak hours, the possibility of opening HOV facilities in the off-peak periods could have merit. However, the differing origins and destinations of commuters and commercial trucks cannot be easily accommodated. HOV facilities often contain design elements that are restricted within the geometric limitation of the surrounding freeway, making accommodation for trucking movements difficult. Weaving movements of trucks can adversely affect mixed-flow operation where median HOV ingress/egress is primarily via these adjacent lanes. There are also some questions about the safety of such a vehicle mix, particularly the effect on sight distances and operating speeds.

Even so, Environmental Protection Agency (EPA) regulations at 40 CFR 88.313-93, which are based on section 246(h) of the Clean Air Act, added by the 1990 Clean Air Act Amendments, allows fleet vehicles from centrally fueled fleets of 10 or more that have been certified and labeled as inherently low emission vehicles (ILEV) to use HOV lanes in certain ozone or carbon monoxide nonattainment areas, regardless of the number of occupants, unless they would "create a clear and direct safety hazard."[32] If ILEVs will be allowed to use HOV lanes, the lanes need to be designed to limit the negative aspects of mixing commercial vehicles and HOVs discussed above.

- **Deadheading Vehicles.** The term "deadheading" refers to transit operators' operating empty buses on HOV facilities for the return trip to their routes. By allowing transit operators to deadhead on HOV facilities, transit services are afforded greater operation efficiency and more visibility on HOV facilities. However, it is not desirable to issue blanket approval of transit operator deadheading, because there are instances where the appearance of empty vehicles on HOV facilities may create a public perception problem. Also, there could be numerous private transit operators in a metropolitan area who may wish to deadhead on HOV facilities, possibly causing unnecessary congestion on the facilities.

- **Emergency Vehicles.** Emergency vehicles are generally allowed on all HOV projects. In practice, however, few emergency vehicles partake of the HOV lanes, because the ingress and egress locations are not generally oriented to the nearest emergency facility (e.g., fire station or hospital). Inclusion of emergency vehicles does not affect the design envelope that is applied, especially if all classifications of buses are accommodated. Any emergency vehicle that uses an HOV facility should be properly identified and involved in a legitimate mission. Use of the lane by off-duty enforcement or unmarked vehicles deteriorates public respect for the operation and its policies and should be discouraged.

MAINTENANCE

Maintenance needs, like incident handling, tend to be the same as for any other metropolitan roadway. HOV lanes can be designed to reduce certain maintenance needs. Following are a few recommendations:[5]

- Drainage inlets should not be placed under barriers. Inlets may be cast into barriers, but slots should be wide enough to be maintained. No inlets should be located in a lane of travel.

- Access to overhead signs should be available. Closed-circuit television, variable message signs and lighting need special attention to ensure that they can be accessed for maintenance without blocking a travel lane.

- Snow removal may require special consideration. This need can dictate the width of shoulders for temporary storage of plowed snow, or intermediate openings in barriers for access by snow removal equipment. HOV lanes should be afforded a higher priority for snow removal than other portions of the roadway.

- Litter removal from the median carries a higher priority on most HOV treatments, particularly on treatments that do not provide adequate lateral clearances with barriers. Even small objects that are blown against a barrier can affect HOV operation. Barrier-separated facilities tend to collect debris blown in from mixed-flow lanes. Some projects have resorted to sweeping or driving the HOV facility in advance of operating periods to remove major obstacles.

- Transit support facilities, most notably bus transfer stations, can be subject to extensive vandalism, and require an inordinate amount of maintenance. Special attention to material selections that are in keeping with anticipated use (staffed versus unstaffed facilities) are recommended.

- The typical one-lane HOV roadway is subject to extensive wear along a specific wheel path. It is not uncommon for ruts in asphaltic concrete surfaces, or tears in the seams between differing pavement materials, to create ongoing maintenance problems. Every effort should be made during the design process to develop a consistent pavement section with sufficient quality for longevity.

- Barriers between parallel directions of travel (HOV and mixed-flow) should be only loosely fixed to the pavement, and barriers preferably precast. This design treatment allows sufficient flexibility in the future to move barriers when the inevitable need arises to handle traffic during pavement resurfacing and rehabilitation activities.

- Pavement markings and HOV signing should be designed with longevity in mind, and properly maintained to minimize confusion and ensure proper operation.

- The design of the HOV facility should not attempt to address every detail. To optimize operation, there will be a need for maintenance activities to address minor modifications to signing, pavement markings and other elements of the project that require some refinement as operating experience is acquired. Capital or maintenance funds should be budgeted for these inevitable needs.

CONCURRENT FLOW LANES

The following issues should be considered when planning and designing concurrent flow HOV lanes:

- Phased construction is sometimes used to build concurrent flow HOV lanes. Often, the finished portions are opened to regular traffic. Converting these lanes to HOV operation can cause opposition and resentment. System planners and operators should either keep the lane free of traffic until it is completely finished or impose HOV restrictions on any opened partial section. In both cases, marketing and public relations campaigns may be needed to explain how the HOV lanes will be used during construction.

- Careful consideration should be given to how vehicles merge into and out of concurrent flow HOV lanes. Designers should be careful not to create a design where unsafe driving conditions are generated because of the speed differential between HOV and regular traffic lanes.

- Concurrent HOV lanes can be used by aggressive drivers to pass slow moving vehicles, and to weave in and out of regular flow traffic. Regular enforcement activities may be needed to curb this activity.

6.5 EXAMPLES OF HOV TREATMENTS

Two case studies of HOV Systems are offered. These studies provide an overview of the HOV facilities in Houston, Texas, and Seattle, Washington.

HOUSTON

Houston, Texas hosts the most extensive network of barrier-separated HOV facilities in the United States.[33] Ultimately, the Houston HOV system will incorporate 166 km (103 mi) of HOV lanes.[34] The Houston HOV system has enjoyed a great deal of success largely due to the coordinated support offered by the Metropolitan Transit Authority of Harris County (METRO) and the Texas Department of Transportation (TxDOT).[33]

The HOV facilities in Houston were created in response to a surge in traffic congestion that began in the 1970s. The City of Houston and TxDOT sought to improve transit operations and reduce traffic demands by increasing vehicle occupancy from an average occupancy of 1.2 persons per vehicle through HOV priority treatments. Houston's HOV experience began with the development and operation of a 14.4 km (9 mi) contraflow lane on the North Freeway (I-45). The contraflow lane hosted only authorized buses and vans and, when opened for use in 1979, was extremely successful. The contraflow lane was operated only for 2.5 hours during each peak period, but was credited with moving over 8000 persons during those times. As a result of the success of the contraflow lane, Houston began development of a large-scale HOV system concept.[33]

Having committed to the development of HOV facilities in Houston, the City of Houston and TxDOT laid plans for the development of a 166 km (103 mi) HOV lane system as illustrated in figure 6-26. While two-direction HOV facilities are being developed, the typical HOV lane in Houston currently provides for reversible operations, and is separated from general-purpose freeway lanes by concrete median barriers (see figure 6-27). The HOV lanes are typically located in the freeway median and measure approximately 6 m (20 ft) in width. Due to geometric constraints, freeway mainlanes and inside shoulder widths were narrowed in some locations to accommodate HOV lane construction.[33]

Access to the Houston HOV facilities is provided by several means and is typically provided at 5 to 8 km (3 to 5 mi) intervals. Most access to the HOV lanes is provided by grade-separated interchanges. At these interchanges, the HOV lane is elevated in the freeway median, and grade-separated ramps are used to convey traffic over the freeway lanes to select local streets, transit facilities, and park-and-ride lots (see figure 6-28). The grade-separated ramps were chosen for their ability to eliminate interference with freeway mainlane operations, enhance safety, reduce travel time, and provide locations for enforcement personnel to operate. The construction costs of the grade-separated interchanges are estimated to range between 2 and 7 million dollars each. In addition to the grade-separated ramps, some access to the median HOV lanes is provided through the use of slip ramps, as shown in figure 6-29.[34]

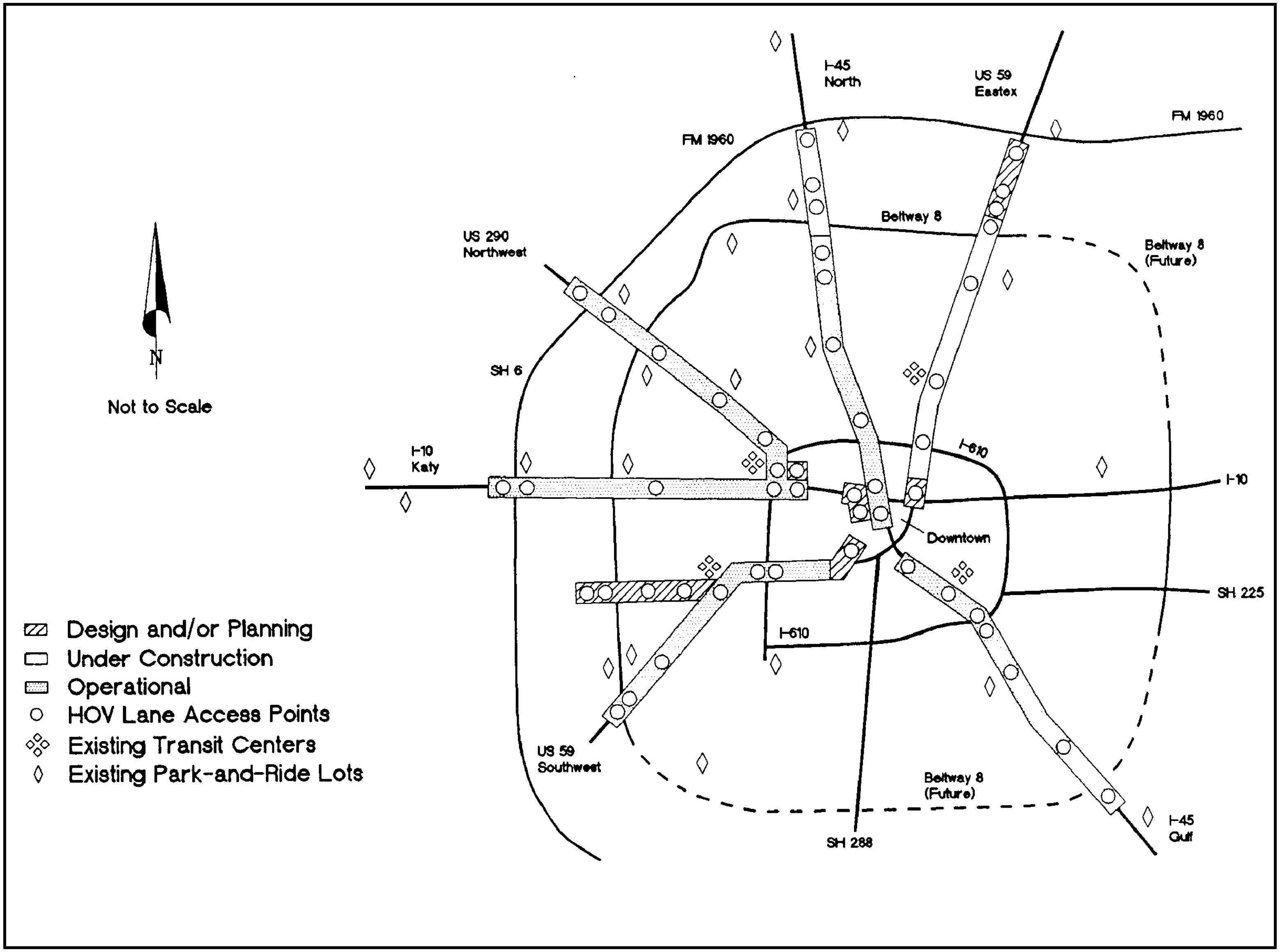


Figure 6-26. Houston HOV System.[34]

Figure 6-27. Typical Houston HOV Lane.[9]

Figure 6-28. Houston Grade Separated HOV Lane Access Ramps.[9]

The occupancy requirements of the Houston HOV lanes, as well as the vehicles that are allowed on them, continue to evolve. Changes have been made to both the occupancy and vehicle requirements to manage traffic volumes on the HOV lanes (see figure 6-30). The changes were made to ensure the desired high speeds and reliable trip times that contribute to the success of HOV lanes.[33]

As of December 1995, the system was hosting in excess of 77,000 person-trips per day.[34] Peak-hour vehicle occupancy has increased by approximately 20 percent on freeways with HOV lanes as compared to their pre-HOV conditions. Freeways without HOV lanes witnessed a decrease in occupancy during the same periods. Given the quasi-independent status of the HOV lanes in relation to the freeway mainlanes, operations on the freeways and other parallel routes have not been significantly affected by the HOV lanes. No significant changes in freeway and parallel route congestion have occurred. This finding is attributed to the HOV's ability to reduce the growth rate in congestion, as opposed to reducing the existing levels of congestion.[33]

Figure 6-29. Houston HOV Slip Ramp.[9]

Figure 6-30. Example of Dynamic Message Sign Showing New Occupancy Requirement.[9]

Contributing to the success of the HOV lanes has been the development of several strategically located park-and-ride lots, transit centers, carpool lots, and downtown bus lanes (see figure 6-31). Park-and-ride lots themselves have experienced a tremendous growth in demand due to use of the HOV lanes. In two of Houston's HOV lane corridors, use of the park-and-ride facilities increased 200 percent or more from pre-HOV levels. Similar corridors not equipped with the HOV lanes experienced only small changes during the same time period. [34]

Travel time savings offered by the HOV lanes have also served as a lucrative means of attracting new users. Because the Houston system is still relatively new, it is not believed to have reached its full potential yet. Nevertheless, time savings range from five minutes on the Gulf Freeway HOV lane to 18 minutes on the Katy Freeway HOV lane. The current 102 km (63.6 mi) system is estimated to result in 41 minutes of time savings, or one minute per mile. Recent survey evidence indicates that the time savings perceived by users of the HOV lanes are much higher and it is expected that future benefits will be even greater as congestion on freeway mainlanes increases.[34]

On the basis of survey evidence, the typical users of the HOV lanes are characterized as young, educated, white-collar commuters. Furthermore, over 90 percent of the transit bus riders using HOV lanes have an automobile at their disposal, indicating a significant expansion of the transit market. Principal reasons cited for using the HOV lanes include the following:[28]

- Freeway too congested (22%).
- Saves time (18%).
- Time to relax (16%).
- Reliable trip time (15%)

Sixty-five percent of the total person trips on the HOV lanes are currently served by vans and carpools. The remaining 35 percent are served by buses. [34]

The latest regional plan for the HOV system estimated that the entire Houston HOV system will have cost approximately $900 million, or $5.5 million per km ($8.8 million per mi), when the system is complete. These costs, estimated in 1995 dollars, include the HOV lanes, HOV lane access and egress ramps, all park-and-ride lots, park-and-pool lots and bus transfer centers, and the HOV surveillance, communication, and control systems. The exact capital cost of the HOV lanes will be difficult to determine because the HOV lanes have usually been constructed in conjunction with freeway renovation projects. [34]

Figure 6-31. Examples of Park-and-Ride Lot and Bus Station.

SEATTLE

Seattle's HOV system is sponsored mainly by the Washington State Department of Transportation (WSDOT) and is eventually expected to include the HOV lanes depicted in figure 6-32. The Seattle HOV system traces its origins to several failed heavy rail and freeway expansion planning projects that were initiated during the 1960s. From those early defeats arose an HOV system that is now considered to represent a long-term component of Seattle's transportation system that doesn't compete with other transit guideway technologies under development. [3]

The first HOV project in Seattle arose as a result of an express bus service demonstration project sponsored by the Urban Mass Transit Association (UMTA) and known as the Blue Streak. The Blue Streak Project involved the operation of eight different transit routes using reversible express median lanes along I-5 in conjunction with downtown ramps. Owing to the success of the Blue Streak program, funding was allocated to further develop and evaluate the Blue Streak program and led to additional HOV operations. In 1972, the Puget Sound Governmental Conference and the regional transit agency published their first transit plan that addressed exclusive/preferential lanes. Further expansion of HOV use came with projects involving I-90 during the late 1970s. During the 1980s, an underground bus tunnel through the downtown area was completed, the I-5 north reversible lanes were extended, concurrent-flow HOV treatments were used on I-5, I-405, and SR 67, and the SR 520 HOV operation witnessed the expansion of its operational hours and eligibility requirements to meet increased demand. [3] Figures 6-33 to 6-35 show typical Seattle HOV facilities.

As each of the HOV projects progressed, the planning process that supported their development evolved. Interagency panel reviews and a task force representing all affected agencies was formed to provide guidance in HOV planning and operations. [3] Public information measures have been used, including telephone and mail-out surveys, newsletters, media events, and other means. In 1992, WSDOT initiated a major policy shift with one of its reports that stated, "When new capacity options are proposed, one of the alternatives to be considered shall be the conversion of a general purpose lane to an HOV lane." In the past, WSDOT had created HOV lanes through construction of new lanes. The first application of this new concept involved the creation of a HOV lane on a 7.5 mile segment of I-90 which had been experiencing lane balance problems. After receiving FHWA approval in the spring of 1993, a combination of lane conversion and new lane construction was undertaken to create new eastbound and westbound HOV lanes. Other sites were later placed under consideration for similar lane conversions.[36]

In most cases, WSDOT serves as the sponsoring agency for HOV lane projects. Funding has been secured from a variety of sources, including a special high-capacity funding package based on regional sales tax revenue.

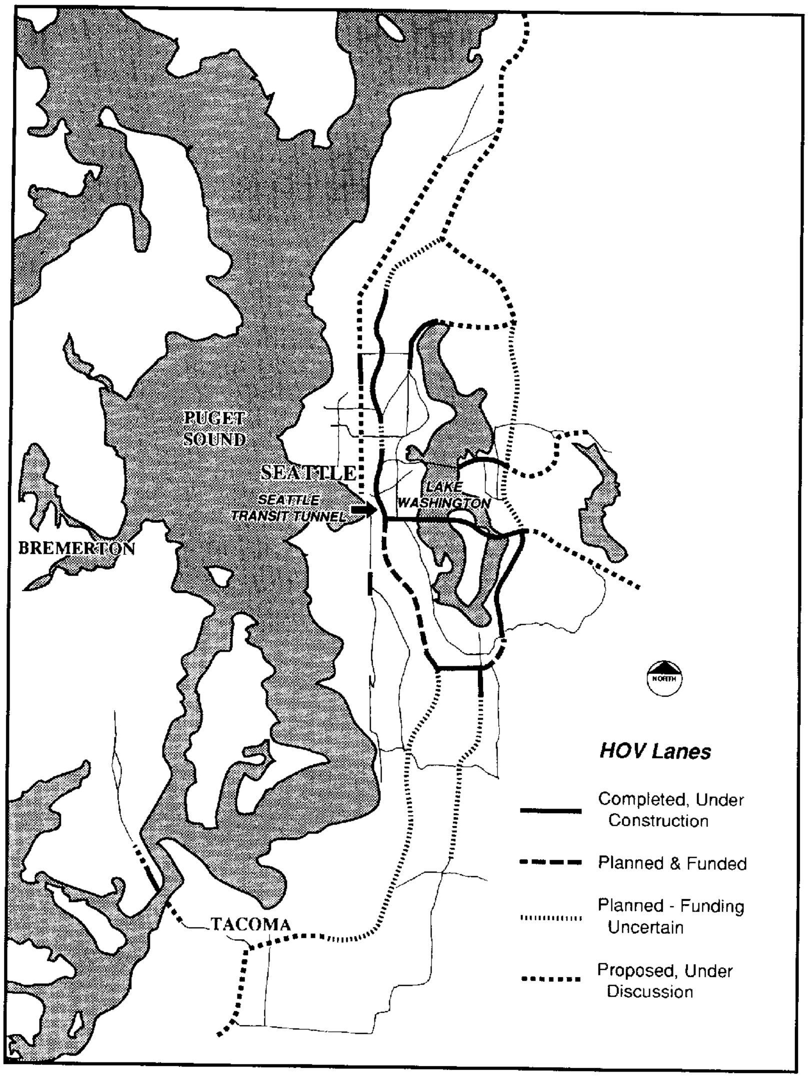


Figure 6-32. Seattle Area HOV System. [35]

Figure 6-33. I-5 Reversible-Flow HOV Lanes. [9]

Figure 6-34. I-5, Seattle Concurrent Flow HOV Lanes (Median Location). [9]

Figure 6-35. I-405, Seattle Concurrent Flow HOV Lanes (Shoulder Location).[10]

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