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1.0. FUNCTIONS OF HOV LANE AND METERED RAMP DESIGN

1.1. Introduction

This is one of several manuals the Nevada Department of Transportation (NDOT) has developed that provide a framework for the study, implementation, design and monitoring of High-Occupancy Vehicle (HOV) and Ramp Metering facilities on major freeways in the State.

The Las Vegas area NDOT and the Regional Transportation Commission of Southern Nevada (RTC) have collectively initiated an effort to install ramp meters and implement HOV lanes along US 95 to mitigate congestion, improve safety and promote more efficient transportation mobility. Both HOV lanes and ramp meters are widely implemented, cost-effective solutions that improve safety and mobility on regional freeway and ramp facilities. HOV lanes promote time savings to ridesharing and transit users by offering a way of bypassing congestion. Ramp meters accomplish these objectives by smoothing the flow of traffic that enters a freeway facility by holding traffic to the ramp, and slowly releasing vehicles in a controlled manner so ramp-based traffic can safely merge with traffic on the freeway.

To be successful in these pursuits, NDOT developed these documents to provide guidance on how to effectively design, implement and monitor HOV lanes and ramp meters. Staff within NDOT and other stakeholder agencies, including RTC, FHWA and the various entities within the State of Nevada that have a stake in implementation and operation, can use this series of documents to ensure that these activities are completed successfully and in a consistent fashion. This Design Manual can be used to gain a high-level understanding of the design issues that should be addressed before ramp meters, HOV lanes and related support facilities are implemented.

1.2. Criteria

The design criteria presented in this manual are intended to augment the NDOT Project Design Development Manual (PDDM), Version 2005:1:1.0 or latest version adopted. The PDDM and the American Association of State Highway and Transportation Officials (AASHTO) Policy on Geometric Design of Highways and Streets (2003 or later edition), “Green Book,” are background sources for many of the standard roadway applications that are illustrated and described. To the extent possible, this manual only provides information not contained in the PDDM. Where there may be real or construed inconsistencies, the PDDM should prevail.

1.2.1. Overview

This manual presents general guidance on how to design HOV/managed lanes and ramp meters in an effective and consistent fashion throughout the State of Nevada. Technical staff and decision makers within NDOT, the RTCs of northern and southern Nevada, as well as the numerous other transportation planning and engineering entities throughout the State, may use this guidance to implement these treatments in a manner that not only improves freeway and ramp operations, but also improves the operation of the implementing agency.
Two design settings are addressed in this guide: new roadway construction and modifications to existing roadways. These two implementation settings can create difficulties in applying a single set of design templates and illustrative treatments. Many more design exceptions may be created where an existing roadway is modified to accommodate an added lane for HOV treatment or ramp metering installation. Accordingly, many of the examples and illustrations for each type of treatment reference a desirable and reduced design condition. The desirable condition is appropriate for any new roadway or fully reconstructed freeway. A reduced condition reflects commonly accepted design deviations or conditional variances among a wide array of implementing agencies for specific conditions and settings. These designs may or may not be acceptable for a specific project setting and may be conditioned for only a specified distance or timeframe.

**Background for Ramp Meters**

Recently, ramp meters have been installed at seven freeway entrance ramps in Las Vegas, four on I-515 and the remaining three on US 95. On March 29, 2005, the three systems deployed on entrance ramps along US 95 were activated. The activation of these metering systems represented the first public exposure to ramp metering within the Southern Nevada region. The activation of meters on I-515 will follow the activation of the meters on US 95, but no specific timeframe has been finalized for I-515. These meters represent the initial deployment of ramp meters. In the future, the system of ramp meters along these routes may be expanded. Similarly, ramp meters may be installed along other freeways within Las Vegas (e.g. I-15 and I-215), the South Nevada region, or elsewhere in the state where traffic problems exist and ramp meters are feasible.

Before ramp meters were considered for deployment within Las Vegas, vehicles had often attempted to merge onto freeways closely spaced with one another. This phenomenon, known as “platooning”, causes drivers on the freeway to slow down to let the merging vehicles enter, and these slower speeds can contribute to time-consuming mainline freeway backups as well as dangerous sideswipe, lane change, and rear-end collisions.

**Background for HOV Lanes**

As part of the reconstruction and widening of US 95 north of I-15 in Las Vegas, HOV lanes were approved as part of the overall project. These dedicated lanes are envisioned to operate concurrently (one lane in each direction of travel) and located next to the median barrier (the inside travel lane). Other reconstruction and widening studies are ongoing within the Las Vegas region, and consideration of HOV lanes may be justified on portions of these routes. A regional study of HOV lanes for the greater Las Vegas area was undertaken in summer 2005 to determine which corridors may be good candidates for HOV lanes. Findings from this study will support subsequent implementation and design activities. For these reasons, design guidance of HOV lanes may be a timely subject as these studies are completed.
1.2.2. Definitions

Information contained in this manual primarily represents guidance in the design of HOV and ramp metering treatments. Definitions found in the PDDM in Section 2.1.2 related to criteria, policy, standard, guide and information are adopted in their application for this manual.

**Terminology**

Terms and criteria described throughout this manual attempt to match terms defined in the PDDM and their application. The most common terminology found in this manual include the following borrowed from the PDDM, Section 2.1.2, Exhibit 2.1-A:

<table>
<thead>
<tr>
<th>Term</th>
<th>Status*</th>
<th>Requirement for Disregarding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shall, Will, Must</td>
<td>Not applied in this manual</td>
<td></td>
</tr>
<tr>
<td>Required</td>
<td>Preferred</td>
<td>Written justification in project file</td>
</tr>
<tr>
<td>Needed</td>
<td>Preferred</td>
<td>Written justification in project file</td>
</tr>
<tr>
<td>Essential</td>
<td>Preferred</td>
<td>Written justification in project file</td>
</tr>
<tr>
<td>Should</td>
<td>Optional</td>
<td>Engineering judgement</td>
</tr>
<tr>
<td>Desirable</td>
<td>Optional</td>
<td>Engineering judgement</td>
</tr>
<tr>
<td>May</td>
<td>Optional</td>
<td>Engineering judgement</td>
</tr>
<tr>
<td>Might</td>
<td>Optional</td>
<td>Engineering judgement</td>
</tr>
<tr>
<td>Could</td>
<td>Optional</td>
<td>Engineering judgement</td>
</tr>
<tr>
<td>Alternate</td>
<td>Optional</td>
<td>Engineering judgement</td>
</tr>
<tr>
<td>Optional</td>
<td>Optional</td>
<td>Engineering judgement</td>
</tr>
<tr>
<td>Reduced</td>
<td>Optional</td>
<td>Engineering judgement</td>
</tr>
<tr>
<td>Minimum</td>
<td>Preferred</td>
<td>Written justification in project file</td>
</tr>
<tr>
<td>Maximum</td>
<td>Preferred</td>
<td>Written justification in project file</td>
</tr>
</tbody>
</table>

* Reference 1.

A variety of terms are frequently used in this manual. Some applications for these terms are referenced to the respective sections noted in the PDDM:

<table>
<thead>
<tr>
<th>Term</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder</td>
<td>Section 2.2.3.3.2</td>
</tr>
<tr>
<td>Shy distance</td>
<td>Section 2.2.3.3</td>
</tr>
<tr>
<td>Sight distance</td>
<td>Section 2.2.3.4</td>
</tr>
</tbody>
</table>

For all other terms, refer to Appendix A.
HOV, Managed Lane and Ramp Meter Definitions

The following definitions are applied to key terms associated with these congestion management strategies:

HOV lanes:

A lane(s) or roadway dedicated to the exclusive use of specific high-occupancy vehicles, including buses, carpools, vanpools or a combination thereof, for at least a portion of the day. Current federal legislation may also conditionally permit HOV lane use to motorcycles and selected types of hybrid vehicles.

Managed lanes:

Highway facilities or lanes in which operational strategies are implemented and managed in real time in response to changing conditions. Managed lanes are distinguished from other traditional forms of lane management strategies in that they are proactively implemented, managed, and may involve using more than one operational strategy.

Ramp metering:

Ramp metering is the deployment of a traffic signal(s) on a ramp to control the rate vehicles enter and merge on a freeway. By controlling the rate vehicles are allowed to enter a freeway, traffic flow on the freeway becomes more consistent, smoothing the flow of traffic on the mainline and allowing more efficient use of existing freeway capacity.

Definitions for many of the terms associated with HOV/managed lanes and ramp metering can be found in the Glossary in Appendix A. For various other terms applicable to this subject and found in the NDOT Project Design and Development Guide, these have been incorporated into the Glossary.

1.2.3. Adopted Reference Documents

References used in the preparation of the HOV/managed lane chapters of this manual include the following:


In addition to the specific references above for HOV design, other documents addressing HOV design considerations include the latest versions of the AASHTO Green Book,
FHWA Manual on Uniform Traffic Control Devices (MUTCD), ITE Freeway and Interchange Geometric Design Handbook (2006) and other references provided at the end of this chapter.

Various other customized documents provide guidance on the design of HOV lanes to regions. California, New York, Washington and the Federal Highway Administration have developed detailed design guidance for HOV lanes. California has a separate guide dedicated to this subject. Washington and New York have sections of their state design manual covering HOV lane treatments. Their respective guidelines have been updated based on experience and design practice, and some of this guidance is available on-line at the following weblinks:

Federal Highway Administration
• http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/hot/index.htm

Washington State
• http://www.wsdot.wa.gov/hov/
• http://www.wsdot.wa.gov/regions/northwest/hovpage/hovmain/htm

California
• http://www.dot.ca.gov/hq/traffops/systemops/hov/hov_sys/guidelines/

1.2.4. General Design Controls and Considerations

**Design Controls**
The same design controls found in the PDDM, Section 2.1.4, apply in this Manual. This includes velocity and vehicle and user types. Specifically, HOV lanes involve the application of transit support facilities often on or adjacent to state right-of-way, and inter-modal considerations for transit, pedestrian, bicyclists, and rail as referenced in the PDDM, Section 2.1.4.5.

Design vehicles for HOV and managed lanes are essentially the same as for general use freeway lanes, governed by the same criteria found in the PDDM. The physical and operating characteristics of users will influence the design of the HOV/managed lane. Listed in Table 1-1 are generalized requirements associated with typical design vehicles.

HOV and managed lanes should generally meet requirements for urban freeway lanes as specified in the PDDM. Listed in Tables 1-2 and 1-3 is guidance from the AASHTO Guide for High-Occupancy Vehicle Facilities (Reference 1) for mainline and ramp treatments.
Table 1-1: Sample Design Vehicle Dimensions

<table>
<thead>
<tr>
<th>Design Vehicle Type</th>
<th>Height</th>
<th>Body Width</th>
<th>Length</th>
<th>Overhang Front</th>
<th>Overhang Rear</th>
<th>Wheel Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Car</td>
<td>4.25 ft</td>
<td>7 ft</td>
<td>19 ft</td>
<td>3.0 ft</td>
<td>5.0 ft</td>
<td>11 ft</td>
</tr>
<tr>
<td>40-ft City Bus</td>
<td>10.5 ft</td>
<td>8.5 ft</td>
<td>40 ft</td>
<td>7.0 ft</td>
<td>8.0 ft</td>
<td>25 ft</td>
</tr>
<tr>
<td>45-ft. Bus</td>
<td>12 ft</td>
<td>8.5 ft</td>
<td>45 ft</td>
<td>6.0 ft</td>
<td>8.5 ft</td>
<td>26.5 ft</td>
</tr>
<tr>
<td>Articulated Bus</td>
<td>11 ft</td>
<td>8.5 ft</td>
<td>60 ft</td>
<td>8.6 ft</td>
<td>10 ft</td>
<td>22 ft front, 19.4 ft rear</td>
</tr>
</tbody>
</table>

Source: Reference 1.

**Design Considerations**

A variety of typical design considerations apply to any form of ramp metering, HOV or managed lane treatment. These include specific designs addressing each type of treatment and specific operation strategies reflected in each design. In almost every instance, technical guidance and examples abound from which to borrow best practices based on many years of experience where these treatments have been implemented. NDOT has already developed design templates as guidance for the implementation of ramp meters, based on recent deployment in Las Vegas. The following section presents various controls and considerations influencing the design of HOV lanes and ramp meters.

**Typical Vehicle Users-HOV**

For HOV lane treatments, typical users include buses, vanpools, carpools and motorcycles. Managed lanes may include all types of vehicles if the lanes are access controlled or priced. Bus turning radii are perhaps the most significant design vehicle issue unique to HOV lanes, since each bus type has a different turning radius. Turning requirements are particularly critical for applications of direct access ramps from transit facilities or where turning at low speeds is required. Common applications include transit support facilities located on or near the freeway such as bus stations and park-and-ride lots.

Visibility is adversely affected in a single platoon of vehicles on a typical HOV lane. Sight distance caused by the mix of buses and lower profile vehicles may reduce vehicle headways, and thus, affect the lane’s operation threshold. Since most HOV lanes are located next to the median, the horizontal separation, or “shy” distance, to the median barrier, where full shoulders cannot otherwise be provided, may adversely affect sight distance around curves. The shy distance, if too limited, can adversely affect an HOV lane’s performance.

Trucks are typically excluded from HOV lanes based on weight or axle count (over three axles is typical). Within North America only one restricted roadway combines large commercial trucks with HOVs. Many states and locales restrict trucks from the leftmost freeway lanes as a matter of operation policy, so the consideration of trucks may run counter to this practice. Truck destinations often are different from commuters, so the access requirements and needs for this group of users may be quite different.
Accommodating trucks in the roadway design of managed lanes only becomes an issue where such facilities are modified onto existing constrained corridors where their provision would adversely affect the project’s cost effectiveness and ability to meet all design vehicle requirements.

Table 1-2: Summary of HOV/Managed Lane Mainlane Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Ramp Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design Speed</strong></td>
<td>In urban areas, a design speed of 70 mph is desirable when the corridor of the mainline is relatively straight and when the character of the roadway and the location of interchanges permit high speeds. Minimum design speed should not be less than 50 mph.</td>
</tr>
<tr>
<td><strong>Stopping Sight Distance</strong></td>
<td>At 70 mph, the minimum stopping sight distance needed is 730 feet. At 50 mph, the minimum stopping sight distance needed is 425 feet.</td>
</tr>
<tr>
<td><strong>Horizontal Alignment</strong></td>
<td>The radius of horizontal curvature used in a particular roadway design is a function of the design speed, rate of superelevation, and the side friction with practical limits due to ROW constraints. As the design speed increases and the rate of superelevation decreases, the minimum radius of horizontal curvature required increases. In an urban environment with a maximum rate of superelevation (e_{max}) of 4% to 6%, the minimum radius at 70 mph design speed is 2,050 feet at (e_{max} = 6%) to 2,345 feet at (e_{max} = 4%). At 50 mph design speed, minimum radius is 835 feet at (e_{max} = 6%) to 930 feet at (e_{max} = 4%).</td>
</tr>
<tr>
<td><strong>Superelevation</strong></td>
<td>The rate of superelevation used in a particular roadway design will be a function of the design speed, radius of curvature, and side friction with practical limits based on driver comfort, safety, climate and local agency standards. As design speed increases and the radius of curve decreases, the need for superelevation increases. AASHTO specifies that in an urban environment, a maximum superelevation rate (e_{max}) of 4% to 6% is common practice.</td>
</tr>
<tr>
<td><strong>Vertical Alignment</strong></td>
<td>Basing the minimum lengths of crest vertical curves (and the rate of vertical curvature) on stopping sight distance criteria is usually sufficient from the viewpoint of safety, comfort, and appearance. In some instances, decision sight distance criteria should be considered. Based on stopping sight distance at 70 mph design speed, the minimum (K = 247). At 50 mph design speed, the minimum (K = 84).</td>
</tr>
<tr>
<td><strong>Rate of Vertical Curvature, K-Crest</strong></td>
<td>The use of stopping sight distance criteria for establishing minimum rates of vertical curvature is recommended. However, three other criteria are evaluated when designing a sag vertical curve, namely passenger comfort, drainage control and general appearance. At 70 mph design speed, the minimum (K = 181). At 50 mph design speed, the minimum (K = 96).</td>
</tr>
<tr>
<td><strong>Rate of Vertical Curvature, K-Sag</strong></td>
<td>Horiztonal and vertical alignment should not be designed independently. See AASHTO Green Book, Chapter 3, Elements of Design.</td>
</tr>
<tr>
<td><strong>Grades</strong></td>
<td>Maximum grades for 50 mph design speed on level or rolling terrain are 4% and 5%, respectively. For 70 mph design speed, maximum grades are 3% and 4%, respectively. Length of grade and design vehicle are important to consider. When the cross slope of the road is adequate to drain the pavement surface adequately, flat grades can generally be used without problem.</td>
</tr>
<tr>
<td><strong>Clearance-Vertical</strong></td>
<td>Desirable is 16 feet and where this minimum vertical clearance would be cost prohibitive in highly urbanized areas, a minimum clearance of 14 feet may be used if there is an alternate freeway facility with the minimum 16-foot clearance. Allowance should be made for future resurfacing.</td>
</tr>
</tbody>
</table>
Table 1-2: Summary of HOV/Managed Lane Mainlane Criteria (Continued)

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Ramp Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearance-Horizontal</td>
<td>See AASHTO <em>Roadside Design Guide</em>.</td>
</tr>
<tr>
<td>Lane Width</td>
<td>HOV lane widths should be 12 feet.</td>
</tr>
<tr>
<td>Cross Slope</td>
<td>Minimum: 1.5% to 2%. Maximum: 2% to 2.5% (center crown).</td>
</tr>
</tbody>
</table>

Source: Reference 1.

Table 1-3: Summary of HOV/Managed Lane Ramp Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Ramp Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Speed</td>
<td>Desirable ramp design speeds should approximate low-volume running speed on</td>
</tr>
<tr>
<td></td>
<td>the intersecting highway. Unlike the middle range of ramp design speeds in</td>
</tr>
<tr>
<td></td>
<td>AASHTO, a 70 mph mainline design speed, minimum ramp design speed is 50 mph.</td>
</tr>
<tr>
<td></td>
<td>For a 50 mph mainline design speed, minimum ramp design speed is 35 mph. For</td>
</tr>
<tr>
<td></td>
<td>a direct connector (flyover) ramp, minimum is 40 mph.</td>
</tr>
<tr>
<td>Stopping Sight Distance</td>
<td>See mainline for minimum. Sight distance on mainlane approach to exit ramp</td>
</tr>
<tr>
<td>(on level roadway)</td>
<td>is preferably 25 percent greater than the stopping sight distance.</td>
</tr>
<tr>
<td>Horizontal Alignment</td>
<td>Use of compound or spiral curve transitions are desirable, being careful that</td>
</tr>
<tr>
<td></td>
<td>the design does not require or encourage unexpected or abrupt speed adjustments</td>
</tr>
<tr>
<td></td>
<td>without proper sight distance. For compound curves, the ratio of the flatter</td>
</tr>
<tr>
<td></td>
<td>radius to the sharper radius should not exceed 2:1 while 1.75:1 is desirable.</td>
</tr>
<tr>
<td></td>
<td>Minimum and desirable lengths of the circular arcs of compound curves for given</td>
</tr>
<tr>
<td></td>
<td>radii are given in the AASHTO Green Book, Chapter 3, Elements of Design.</td>
</tr>
<tr>
<td>Superelevation</td>
<td>See mainline. Algebraic difference in cross slope between auxiliary land and</td>
</tr>
<tr>
<td></td>
<td>adjacent through lane should not exceed four to five percent with 35 mph or</td>
</tr>
<tr>
<td></td>
<td>greater speed of exit or entrance curve. Three ramp segments, exit terminal,</td>
</tr>
<tr>
<td></td>
<td>ramp proper, and entrance terminal should be analyzed in combination to</td>
</tr>
<tr>
<td></td>
<td>determine the appropriate design speed and superelevation rates.</td>
</tr>
<tr>
<td>Vertical Alignment</td>
<td>See mainline. Ramp profiles usually take on the shape of an “S” curve, with a</td>
</tr>
<tr>
<td></td>
<td>sag vertical curve at the lower end and a crest vertical curve at the upper</td>
</tr>
<tr>
<td></td>
<td>end.</td>
</tr>
<tr>
<td>Alignment Combined</td>
<td>See mainline.</td>
</tr>
<tr>
<td>Grades</td>
<td>Ramp terminal profiles are determined by required mainline profiles. Ramps</td>
</tr>
<tr>
<td></td>
<td>with bus traffic: desirable maximum is five percent for short upgrade and the</td>
</tr>
<tr>
<td></td>
<td>desirable maximum is three to four percent for downgrade with sharp horizontal</td>
</tr>
<tr>
<td></td>
<td>curvature.</td>
</tr>
<tr>
<td>Clearance-Vertical</td>
<td>See mainline.</td>
</tr>
<tr>
<td>Clearance-Horizontal</td>
<td>See mainline.</td>
</tr>
<tr>
<td>Lane Width</td>
<td>Travel-way width: 14 feet to 30 feet. See AASHTO Green Book, Chapter 10.</td>
</tr>
<tr>
<td>Cross Slope</td>
<td>Tangent sections: Minimum 1.5%. Maximum 2.0% (one-way).</td>
</tr>
</tbody>
</table>

Source: Reference 1.

Motorcycles in the U.S. are considered eligible for any HOV lane unless safety issues are identified that would preclude them. The latest federal legislation also allows consideration of hybrid powered vehicles if they meet specific performance requirements, and from a design requirement, will probably not influence a specific facility design. Emergency vehicles responding to an incident are usually exempted by local practice,
and depending on the facility design, may need special access considerations addressed if the HOV or managed lane is physically separated from other lanes. Managed lanes are typically open to all traffic except perhaps large trucks, and are best designed for general traffic conditions following guidance from the NDOT Design Guide and AASHTO Green Book.

**Typical Vehicle Users-Ramp Metering**
Ramp metering should address all classifications of vehicles allowed to use state designated controlled access roadways.

**Operation Policy**
Ramp meters and some HOV lanes operate only during selected hours in the peak period. At other times the ramp is not metered. An HOV lane may be restricted full time or not restricted and open to all traffic during off-peak periods. Changes in how a ramp or dedicated HOV lane operate need to account for easy user understanding of the prevailing operation policy and how this policy is communicated on signs, pavement markings and other traffic control devices employed. If the lane is open to all traffic, then how the lane is differentiated or physically separated may promote confusion outside the operating period. Even if a HOV lane is operated on a 24-hour basis, this intent needs to be communicated because surrounding states may have projects that operate only part-time. The Policy and Implementation Guides address the process for establishing an operation policy. Before design is undertaken, a clear understanding of this policy should be the basis for design selection and application. The most common failing of many HOV lane designs is failure to account for potential or anticipated changes in operation policy that may be caused by a need to alter who is eligible and how the facility is operated. These changed conditions are hard to address later on.

Managed lanes involving pricing may operate on a full-time basis. To best manage demand, full-time operation may require a price change throughout the operation period to coincide with periods of high or low demand. In this manner, communicating the prevailing price and related time savings benefits may be a requirement in the design of any managed lane.

**Restrictions on Eligibility and Periods of Use**
A vast majority of HOV lanes, including bypass lanes at ramp meters, are restricted to two or more persons per vehicle. The latest federal guidance encourages local policies be adopted to define proper restrictions for HOV lane use. Restrictions need to be clearly presented to motorists on signing approaching and within the restricted lane treatment.

Changing user and lane restrictions will require modifying the requisite signing and markings, as appropriate.
HOV Lane Orientation

Typically, freeway HOV/managed lanes are located adjacent to the median to avoid conflicts with local ramps and associated merging with local access ramps. Median orientations are also more amenable to limiting HOV lane ingress and egress and discouraging shorter distance trips from using the HOV lane. Median oriented breakdown shoulders are typically used by both HOVs, and right side shoulders used by general traffic. However, most concurrent HOV lanes would permit traffic from either roadway to use whatever shoulder is most convenient, even if access restrictions exist between the HOV and general purpose lanes.

Median oriented HOV lanes do not work well for transit services that require frequent loading and unloading of passengers, because buses can spend more effort merging into and out of the dedicated lane than benefiting from it. Median bus stations should be considered for this type of service and lane orientation, or the transit service plan should be tailored to more point-to-point express non-stop service that does not require intermediate stops.

Outside shoulder HOV lane treatments on freeways are not suitable to a heavy volume of mixed buses and carpools. Such treatments can be workable for short distances to serve as a bus queue bypass between successive local access ramps, and for temporary settings where transit stops may already be in existence. One locale has relocated right side HOV lanes to the median as demand has grown (Figure 1-1). Borrowing an inside shoulder for high-speed HOV lane traffic is not encouraged, as the temporary use of a breakdown shoulder for a moving lane can confuse motorists and create a safety hazard. Outside shoulder use should be clearly signed, speeds reduced for shoulder users, and conditions closely monitored.

Figure 1-1: I-405 HOV Lane Before and After Conversion to Inside HOV Orientation in Seattle Area

Separation from Adjacent Lanes

If an HOV restriction is applied on a part-time basis and the lane reverts to general use at other times, then the lane should not be so differentiated that it causes motorist confusion.
during non-restricted periods. About half of HOV lanes currently operating in the U.S. are part-time and are separated only with a pavement marking stripe that meets MUTCD requirements.

However, for full-time operations and where HOV volumes are high, some additional form of separation is encouraged. A painted buffer is commonly applied as exemplified in Figure 1-2. Painted buffers or provision of physical separation promote more efficient traffic flow where travel speed differentials in adjacent lanes can be quite high, and these treatments may improve operational safety. Managed lanes employing pricing may need some form of physical separation (e.g., hard concrete barriers or soft pylon barriers) to deter toll evaders. Specific requirements for lane separation can be found in Section 3.1.1.

![Figure 1-2: Buffer Separated HOV Lane in Southern California](image)

**Access**

When lane demand is high or accessing movements constitute a large percentage of total users, regulating access is encouraged. Access restrictions and dedicated access ramps are ways to promote a more orderly flow of traffic in these settings. A wide variety of access treatments have been demonstrated on HOV and managed lanes. Experience is still being gained on the best ways to handle large volumes of vehicles on multi-lane roadways. The current best guidance for such settings is to provide the same level of design common to multi-lane freeways. Specific guidance on access for each major type of HOV/managed lane treatment is found in Section 3.2.

**Enforcement and Incident Management**

A managed roadway must provide a high degree of reliability to be effective. Rules and regulations associated with management tools are different from regular traffic lanes. Enforcement may be aided by new technologies to address toll evaders, but some on-site presence may still be needed, particularly for occupancy enforcement. The facility’s operation rules and prices for use may change from peak to off-peak conditions, or from day to day. Such changes can complicate the role of enforcement and incident management. Every HOV project has benefited when these personnel are brought in
early in the design process, and when provisions were included to help promote safe and effective enforcement practices. Some example provisions include wide shoulders, barrier protection, dedicated enforcement areas with good visibility, frequent and clearly understood signing and adequate lighting. On some projects dedicated personnel are made available and are separately funded for this role. More detailed information describing unique enforcement design provisions for different facility types is included in Section 3.3.1.

1.3. Design Exceptions or Variances

Many locales have implemented HOV lane designs in very constrained geometric settings. Design feasibility may require design exceptions or variances. The application and study of each situation is often site-specific. The presentation of reduced and minimum design examples in this manual is intended to reflect these different contextual settings. Guidance for studying and addressing design exceptions can be found in the PDDM, Section 2.1.5, and is applicable to facilities discussed in this manual.

SECTION REFERENCES


2.0. METERED RAMP DESIGN

This section addresses major design elements associated with ramp metering. Since the focus of this chapter is on the design issues and elements specific to ramp metering, design issues of general ramps is not addressed.

2.1. General Layout of Ramp Meter Elements

Ramp meters may be installed on existing or newly constructed ramps. Each design element identified in this section should be considered whether it is new ramp construction or an existing ramp being retrofitted with a ramp meter. Figure 2-1 shows a typical layout of metering elements of a one lane metered ramp. This figure shows the stop bar and the general layout of detection devices. The location of the ramp meter (not shown) for the lane configuration shown would be located on the left side of the ramp near the stop bar. Where possible practitioners should use NDOT approved designs and measurements when designing or retrofitting ramps for metering operations (see Figure 2-2 through Figure 2-6).

2.1.1. Meter and Stop Bar Location

The location of a ramp meter and stop bar must strike a balance between available queue storage space on the ramp and acceleration distance to the freeway. The ramp meter and stop bar should be located at a position on the ramp that gives vehicles enough distance to accelerate to freeway speeds and merge safely with freeway traffic. Acceleration distance can be calculated using AASHTO standards. A minimum distance of 300 feet should be provided from the stop bar to the end of the physical separation between the metered ramp and the mainline. For loop ramps, the ramp meter and stop bar should be located near the freeway gore point, provided adequate acceleration distance is present parallel to the mainline. In either case, locating the ramp meter and stop bar further down the ramp will maximize the available storage space on a ramp. This may be particularly beneficial if restrictive metering rates are used and long vehicle queues are expected.

2.1.2. Number of Lanes

The number of required lanes on a metered ramp should be based on the ramp volume, required queue storage, ramp meter release rate (either one or two vehicles allowed per green), and available ramp width. Available ramp width may be based on the existing ramp pavement or the pavement width feasible based on geometrics and topography. Shoulders may also be utilized when ramp meters are operating to increase the number of effective lanes, thereby increasing the queue storage capacity. The estimated queue and available storage distance to the upstream intersection will have an influence on the number of lanes needed.

In general, the maximum discharge rate of a single metered lane is 900 vehicles per hour (veh/hr). This is calculated using a minimum cycle time of 4 seconds (2.5 seconds of red plus 1.5 seconds of green). The lowest practical discharge rate is 240 veh/h, which is based on a 15-second cycle time.1 Refer to Table 2-1 for general guidelines on appropriate ramp volumes for single or dual release rates.
Figure 2-1: General Layout of Ramp Meter Detectors (One-lane Metered Ramp)
Table 2-1: Number of Ramp Lanes/Meters Based on Ramp Volume*

<table>
<thead>
<tr>
<th>Flow Control Scheme</th>
<th>No. of Lanes</th>
<th>Cycle Length</th>
<th>Approximate Range of Metering Rates (v/hr)</th>
<th>Capacity (veh/hr)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Entry</td>
<td>1</td>
<td>4 – 4.5 sec.</td>
<td>240-900</td>
<td>900-1000</td>
</tr>
<tr>
<td>Dual Entry</td>
<td>1</td>
<td>6 – 6.5 sec</td>
<td>240-1100</td>
<td>1100-1200</td>
</tr>
<tr>
<td>Multi-Lane</td>
<td>2</td>
<td></td>
<td>400-1700</td>
<td>1600-1700</td>
</tr>
</tbody>
</table>

* Depending on driver behavior capacities slightly greater than those shown may be applicable.

**Single-lane Metered Design**

Single-lane metered ramp design can allow for single or dual vehicle (i.e., Platoon) release rates depending on the desired flow rate. Single-lane ramps with a single vehicle release rate should be provided for volumes up to 900 vehicles per hour. Single-lane ramps with a dual vehicle release rate should be provided for volumes up to 1100. Depending on driver behavior, slightly greater volumes (up to 1000 vehicles and 1200 vehicles respectively) may be accommodated.

Depending on the design of the ramp, metered ramp designs shown in Figure 2-2 and Figure 2-3 are typically applied. In addition to the one metered lane, it is also possible to add an HOV bypass lane. A typical one lane metered ramp with an HOV bypass lane is shown in Figure 2-4.

**Multi-lane Metered Design**

Multi-lane metered ramps can be used to increase the overall vehicle storage within the available ramp length or to accommodate demands that exceed the capacity of a single metered lane. This design requires not only adequate acceleration distance from the stop bar to the freeway entrance, but it also requires adequate distance for the multiple lanes to merge prior to the freeway entrance.

Multi-lane metered designs can release vehicles simultaneously, alternating between the lanes, or independently. With multiple lanes, it is possible for each lane to operate with a different metering rate. A typical two lane metered ramp design is shown in Figure 2-5. Similar to the one lane metered ramp design, an HOV bypass lane may be provided on a two lane metered ramp. A typical two lane metered ramp with an HOV bypass lane design is shown in Figure 2-6.
Figure 2-2: Typical One Lane Metered Ramp
Figure 2-3: Typical One Lane Meter Ramp (Clover Leaf or Loop Ramp)
Figure 2-4: Typical One Lane Metered Ramp with HOV Bypass Lane
Figure 2-5: Typical Two Lane Metered Ramp
Figure 2-6: Typical Two Lane Metered Ramp with HOV Bypass Lane
2.1.3. Freeway-to-Freeway Metered Design

Freeway-to-freeway ramp metering consists of metering a ramp that connects one freeway to another. Freeway-to-freeway ramp metering may be used when it is more advantageous to meter a freeway spur than nearby entrance ramps upstream of the location where the two freeways connect. It is critical in this high-speed environment that adequate sight distance and sufficient advance warning be provided for motorists, as they will likely not be expecting to stop. A recommended practice is to install a sequence of two signs in advance of the metered freeway-to-freeway connector.

2.1.4. Queue Management

Required queue storage is based on the metered ramp volume, metering rate, release rate, and vehicle length. Queue lengths can be roughly estimated using the Mn/DOT general rule of 10 percent of the pre-metered peak hour volume.\(^1\) Thus, if the peak hour volume is 500 veh/h, storage for 50 vehicles should be sufficient. This storage requirement can then be converted from vehicles to distance by multiplying the vehicles required by the average vehicle length (can be estimated at 25 feet or calculated through field measurements). It is desirable to contain the ramp meter queue within the limits of the ramp. However, there are times when the queue may extend beyond the available storage on the ramp. In these situations, there are several methods for handling the additional overflow queues. More precise queue storage measurements can be calculated using an assortment of simple to complex traffic analysis tools.

1) Provide additional storage on surface streets. A portion of the surface street is used to store vehicles from the ramp queue. This requires traffic signal retiming at nearby intersections to reduce the impact of the ramp queue on non-freeway bound traffic.

2) Adjust the metering rate to reduce the queue. This will have a negative impact on the freeway operation, but it will prevent the queues from disrupting local arterial operations. When reducing the queue, it is important not to “dump” the entire queue onto the freeway in order to relieve the backup.

There are various locations where detection can be used to assist with queue management (i.e. mid-ramp and end-ramp detection). Ramp queue detection is used to monitor the queue length and adjust the metering rate prior to the queues becoming excessive. It is beneficial to install this additional detection because with it queues can be monitored and reduced before they cause operational problems.

3) Allow platooning. Platooning can permit two or three vehicles per green (allowing two vehicles per green is also referred to as a dual release rate). Allowing two vehicles per green can increase the practical limit of a single-lane on-ramp from 900 to approximately 1,200 veh/h as presented in Table 2-1.

4) Some traffic will naturally divert because of ramp metering and seek routes without queues or meters. There are some ways to inform drivers of the delays so that they can make an informed choice. Where queuing is more severe, an active management approach can be taken to address the queuing with signs upstream of the ramp that inform motorists of the traffic delay. For example, a dynamic message sign (DMS) with the specific delay time, or a simple blank-out sign, could be activated when the queues are unacceptable. Blank-out signs deployed on surface streets adjacent to the freeway can be used to guide motorists to other, less congested ramps when severe queuing on the metered ramp occurs.
2.1.5. HOV Bypass Lane

To encourage the use of carpools, vanpools, and transit, an HOV bypass lane may be added to metered ramps to allow occupants of these modes to bypass queues that form as a result of metering. However, HOV bypass lanes should not be considered if policies are not in place to support them and if they are not part of a broader HOV plan. If policies are in place, HOV bypass lanes may reduce the length of queues that form at meters (HOVs typically make up anywhere from 10 to 25 percent of the traffic volume). The bypass lane can be used for transit vehicles only or all HOVs.

If a dual left turn lane feeds a single metered lane and an HOV bypass lane on the ramp, one must consider the most appropriate lane allocation for the left turn lanes. If there are a considerable number of HOVs in the left turning traffic stream, the left turn lane directly feeding into the HOV bypass lane could be designated for HOVs only during times when the ramp is metered. This lane assignment would ease access to the HOV bypass lane and reduce weaving on the ramp. If the metered ramp has sufficient length and the left turns have a lower HOV volume, another option would be to keep both arterial dual left turn lanes open to all vehicles and provide for merging to the HOV bypass lane on the metered ramp itself.

Considerations should also be given to the right turn movements from the arterials to the metered ramp, especially in deciding which of the two ramp lanes should be designated as the HOV bypass lane. If there is a large volume of right turning traffic with significant HOV volumes, the configuration that will minimize HOV delay and weaving in general should be selected. If the right lane from the arterial is a drop lane to the ramp, then the HOV bypass lane should be located on the right side which would prevent the high volumes of HOVs from weaving. On the other hand, if there are minimal HOV volumes, then the rightmost through lane could be designated as a through lane and right turn lane for HOVs only. In this case, the left lane on the ramp should be designated as the HOV bypass lane.

2.1.6. Enforcement Areas

Design features of enforcement areas such as the locations and dimensions of areas, should be discussed with enforcement agencies prior to and throughout final design. Enforcement areas may be on the metered ramp itself or in a nearby area with line-of-sight to the ramp meter. At a minimum all ramps with two or more metered lanes should have an enforcement area on the ramp. The enforcement area should be located on the right side for queue bypasses and downstream from the stop bar so that the officer can be an effective deterrent. The overall length of the enforcement area may be adjusted to fit the specific conditions on the metered ramp. On single-lane metered ramps, a paved enforcement area is not necessary, but the area should be graded to facilitate future ramp widening. General positioning of an enforcement area is shown in Figure 2-1.

2.2. Equipment

This section describes the equipment that should be installed at each metered ramp. At a minimum, ramp meter hardware consists of a ramp controller, signal heads, signal pole(s), and detection devices.
2.2.1. Ramp Controller

The controller assembly consists of a cabinet, controller, load switches, input files, loop amplifiers, and other devices similar to a traffic signal at an intersection. The ramp controller typically acts as a data station as well as a signal controller. NDOT currently uses type 170s for ramp controllers. The 170s are microprocessor-based devices that control ramp meter signals using information from the loop detectors.

The controller cabinet must be placed where it is easy to access for maintenance, allows a technician to see the signal heads, does not block a vehicle’s sight distance, and is protected from errant vehicles. Other factors that may affect placement of the ramp controller assembly include:

- Safety of the cabinet location (a cabinet should not be placed on the outside of a curve).
- Grade
- Drainage

Other necessary features include the ability to provide accessible power source and communication with the traffic control center. Communication can be provided via telephone lines, fiber-optics, microwave, or radio frequencies (RF).

2.2.2. Signals

For single-lane metered ramps, a type I signal pole (vertical pole only) with a minimum of two signal heads should be located on the left side of the ramp, adjacent to the stop bar. For two-lane metered ramps, a type I signal pole can be located on each side of the ramp or a mast arm style signal pole with overhead signal heads can be used. For metered ramps with two metered lanes and an HOV bypass lane, a mast arm signal pole should be used. A mast arm should also be used for three lane metered ramps (with or without an HOV bypass lane). All signal poles should be located in a clear zone to reduce the potential for “knock-down.”

The MUTCD provides standards for placement and location of all traffic signal devices. Practitioners should refer to Sections 4D and 4H of the latest edition for updated guidelines. Practitioners can also refer to the typical ramp meter sign details shown in Figure 2-7.

Mast arm signal poles requirements:

The distance from the stop line to the signal faces is typically 60.7 feet. The distance shall not be less than 40 feet or more than 180 feet, unless a supplemental near-side signal face is provided.

- The height of the signal housing over the roadway shall not exceed 25.6 feet.

Signal head placement:

- Mast arm signal poles - one signal head shall be located over each metered lane.
- Signal heads are not needed for un-metered lanes, such as an HOV bypass lane.

Signal heads:

- A minimum of two signal heads are required (red and green), regardless of the number of lanes. Typically signal heads are LED.
- Signal faces need not be illuminated when not in use.
- If metering operations will be enforced, than a single red light should be provided on the opposite side of the signal pole. This lets the enforcement officer located downstream of the ramp meter know when the red signal indication is active.
Figure 2-7: Typical Ramp Meter Sign Details

Legend and border: black
Background: white
Corner radius: 1.0"
Border: 0.025"
Margin: 0.375"

Sign Detail A

NOTES:
1. Ramp meter signal poles shall be located in clear zone or behind guardrail or barrier wall.
2. Cabinets not protected by guardrail shall be located outside of the clear zone. Signage and light shall be visible from the cabinet.
3. For installation behind guardrail, mounting height shall not exceed pole height. Adjust pole height as necessary.
4. Conduit and pull box locations are representative. See plan sheets for size and layout.
5. LED meter-on-sign shall be for mounted under the meter-on-existing signal pole. See plans.
7. Meter on head shall be yellow in color.
8. Install and spliced W14-14 conductors in pole and meter panel to power cables and run to ramp meter head.

State of Nevada Department of Transportation
Typical Ramp Meter Sign Details

Nevada Department of Transportation
24
HOV/Managed Lanes/Ramp Metering Design Manual
2.2.3. Detection

Detectors or detection fields are required at specific locations on the metered ramp and on the freeway mainline at a location upstream of the ramp-freeway merge. Detection can be implemented in the form of induction loops or video detection. Other detection devices could be used if more suitable for the application.

The detector locations are related to the detector functions. Figure 2-2 through Figure 2-6 show typical locations of loops and detection fields for demand, passage, and ramp queue detectors for various ramp and lane configurations. Typically, mainline detectors are placed 500ft. upstream of the entrance ramp gore point. The placement of detectors must be reviewed and approved by the operations staff before implementation begins.

Demand

Demand detectors are installed in each metered ramp lane, just in advance of the stop bar. The demand detection zone provides coverage in the area just upstream of the stop bar, and operates as a typical traffic signal stop-bar detection zone. Demand detectors sense the vehicle’s presence at the stop bar and initiate the green traffic signal display for that specific lane.

Passage

Passage detectors are installed immediately downstream of the stop bar. The passage detection zone provides coverage downstream of the stop bar in each metered lane. Passage loops are used to count the number of vehicles that enter the freeway. This information can be used to determine the duration of the green signal display.

Mainline Detector

Mainline detectors provide freeway occupancy, speed, and/or volume information that are used to select the local, traffic-responsive metering rate. These detectors can also provide data for centralized ramp metering and incident detection algorithms. Several mainline detection zones are required for ramp meter operations. In isolated operations, the mainline detection zone is located upstream of the entrance ramp gore point.

Ramp Queue

Ramp queue detectors monitor excessive queues that cannot be contained within the queue storage area, and they provide input to maximize the metering discharge rate to clear excessive queues. This helps prevent queues from spilling onto the local streets and disrupting arterial operations. One loop per entrance ramp lane should be installed near the ramp/arterial intersection. Intermediate queue detectors may be added to the ramp as well. These intermediate loops will help to identify when the queues are beginning to fill the ramp capacity.

Exit Ramp Detector

Exit ramp (or off-ramp) detector loops should be installed for traffic count information. One loop per exit ramp lane should be installed.

Entrance Ramp Detector for Ramps without Meters

For system-wide, traffic responsive ramp meters, detection is important on the entrance ramps that are not metered. Accurate corridor count data ensures that the proper metering rates are
implemented at the metered ramps. Data from these detectors can also be used for a variety of other applications, including performance monitoring and transportation planning.

2.3. **Lighting**

All metered ramps, regardless of their configuration must be lighted to make visible all pavement markings and signs on the ramp.

2.4. **Signing**

The potential for motorist confusion increases as the metering layout becomes more complex (i.e., more lanes, bypass lanes, signal heads, etc.). In addition, not all motorists are familiar with ramp metering operations. Thus, signing and pavement markings for ramp metering must be as clear as possible. The type of signing and pavement marking that should be used, however, is dependent on the type of meter that is implemented. This section discusses the signing options and pavement markings that should be applied to metered ramps.

All projects requiring permanent signs require a set of plans as soon as possible after the geometric (preliminary design) review. This set of plans should show the location of all traffic lanes (through travel, ramps, auxiliary lanes, lane drops, transitions, etc.); theoretical gores; crash attenuators; longitudinal barriers; traffic islands; bicycle facilities, bridge structures (with provision for sign attachment); and any other situations that may affect signing.

2.4.1. **Standard Ramp Metering Signs**

There are a variety of signs that are used for ramp metering. The type of signs that need to be deployed depend on the type of ramp meter design. Various types of signs that may be used for ramp meter design are described below. Only signs specific to ramp meter operations are provided.

**Advance Warning**

Advance warning signs give motorists advance warning that ramps are metered as well as the status of metering operations. Advance warning signs should be posted on every arterial approach that leads to a metered ramp. An advance warning sign like that presented in Figure 2-8 should be placed on the right side of the arterial, approximately 200 feet upstream of the ramp entrance point. Depending on the geometry of the ramp, it may be necessary to post advance warning signs along the ramp as well. An advance warning sign like that presented in Figure 2-9, may be posted on ramps where a meter is not visible in time for a motorist to bring his/her car safely to a stop.
Advance warning sign like those presented in Figure 2-8 and Figure 2-9 should be deployed with a yellow flashing beacon that is activated during metered periods to alert motorists of the upcoming controlled ramp. See Figure 2-3 for signing details for the “RAMP METERED WHEN FLASHING” sign with yellow beacon.

**Form 2 Lanes When Metered**

Signs that read “FORM 2 LANES WHEN METERED” are regulatory signs used to convert the single lane on-ramp into a dual-lane queue storage reservoir during metered operations. These signs should be positioned near the beginning of the dual-lane queue storage reservoir on the right side of the on-ramp (or positioned on both sides of the ramp). A typical “FORM 2 LANES WHEN METERED” sign is shown in Figure 2-10.

**Shoulder May be used During Metering**

This sign is used to inform motorists of the conditional use of the shoulder if queues on the main ramp are backing up. This sign is similar to the “FORM 2 LANES WHEN METERED” sign above. This sign is placed upstream of the ramp meter.

**Stop Here on Red**

This regulatory sign identifies the signal stop bar location and is used to align drivers over the demand detectors placed immediately upstream of the stop bar. These signs should be placed on both sides of the entrance ramp at the stop bar. This sign is attached to the signal pole under the post-mounted configuration. A typical “STOP HERE ON RED” sign is shown in Figure 2-11.
This regulatory sign is used to inform motorists of the intended traffic control method or release rate for ramp meter operations. When dual release rates are used it is necessary to change the wording of these signs to “TWO CARS PER GREEN EACH LANE”. In either case, these signs should be placed either on the signal pole or with the “STOP HERE ON RED” regulatory sign under a mast arm configuration. The NDOT approved “ONE CAR PER GREEN” sign is shown in Figure 2-12.

**Figure 2-12: NDOT Approved “ONE CAR PER GREEN” Sign**

This regulatory sign is used to inform HOV traffic to do not stop. This sign should be posted on the same side as the HOV bypass lane, upstream of the meter. The NDOT approved “DO NOT STOP” sign for an HOV bypass lane is shown in Figure 2-13.

**Do Not Stop**
Be Prepared to Stop
This advance warning sign informs motorists that the ramp meter is turned on. This sign is placed upstream of the ramp meter. An advance warning sign that displays the words “BE PREPARED TO STOP” is shown in Figure 2-14.

Figure 2-14: Typical “BE PREPARED TO STOP” Sign (W3-4)

Traffic Signal Ahead
This warning sign is used to inform motorists that a traffic signal is ahead and to be prepared for the potential to stop. This sign is placed upstream of the ramp meter. A typical sign used to indicate that a traffic signal is ahead is shown in Figure 2-15.

Figure 2-15: Typical Traffic Signal Ahead Sign (W3-3)

Merge Signs (Left and Right)
Warning signs are used to inform motorists of the need to merge with another ramp lane prior to entering the mainline. If the left lane merges with the right lane (i.e., left lane drop) the sign shown in Figure 2-16 should be posted on the left side of the ramp approximately 100 feet downstream of the stop bar. If the right lane merges with the left (i.e., right lane drop) the sign
shown in Figure 2-17 should be posted on the right side of the ramp in approximately the same location (i.e., 100 feet downstream of the stop bar).

A sign that reads LEFT LANE ENDS (Figure 2-18) or RIGHT LANE ENDS (Figure 2-19) should be posted on three-lane ramps with congruent double tapers (one from each side of the ramp, merging into the center lane) to eliminate confusion that may result if signs presented in Figure 2-16 and Figure 2-17 are posted on opposite sides of the metered ramp. If both the left lane drop and right lane drop signs (Figure 2-16 and Figure 2-17 respectively) are posted together, motorists may falsely interpret the use of these signs as 4 lanes merging into 2. Instead, the left-lane drop sign should be used with the RIGHT LANE ENDS sign or the right lane drop sign should be used with the LEFT LANE ENDS sign. If an HOV bypass lane is present on the metered ramp, and is located on the left side of the ramp, the LEFT LANE ENDS sign should be posted on the left side of the ramp. Similarly, if an HOV bypass lane is located on the right side of the ramp, the RIGHT LANE ENDS sign should also be posted on the right side.

**Figure 2-16:** Typical Sign for Left Lane Drop (W4-2)  
**Figure 2-17:** Typical Sign for Right Lane Drop (W4-2)

**Figure 2-18:** Typical “LEFT LANE ENDS” Sign (W9-1)  
**Figure 2-19:** Typical “RIGHT LANE ENDS” Sign (W9-1)

### 2.4.2. General HOV Signing

HOV designation signs are required to establish the definition of HOV along the facility (i.e., two- or three-person carpools, transit only, etc.). These signs should clearly indicate the lane(s) designated as HOV so motorists can make appropriate lane choices before lane restrictions occur. Typically, these signs are placed at the entrance of a ramp, however they may also be placed along the ramp as reinforcement, if the HOV bypass lane exceeds 400 feet in length. A sign, such as that shown in Figure 2-20, may used to indicate when HOV restrictions are valid (e.g., “ONLY WHEN METERED”) if not used on a permanent basis. An alternative to the sign presented in Figure 2-20, is a sign like the one presented in Figure 2-21 or Figure 2-22 that indicates the specific time-of-day HOV restrictions are valid. A sign like that presented in Figure 2-23 should be used when HOV restrictions are permanent (i.e., not by time-of-day or “ONLY WHEN METERED”).
2.4.3. Freeway-to-Freeway Metering Signs

Warning motorists of the metered operation is important as motorists do not expect to stop on ramps. This is especially true for freeway-to-freeway metering applications. Advance warning signs are recommended in advance of all metered ramps, including freeway-to-freeway metered ramps. There are different types of warning signs that can be used. These signs may be internally illuminated or accompanied by flashing beacons to draw attention.

Figure 2-3 (Detail D) shows an example of an extinguishable message sign for a freeway-to-freeway ramp metering application. High visibility is a crucial requirement for these signs because motorists do not expect to stop on the freeway. The “Meter On” sign should be installed downstream from the point of the exit gore area. A recommended placement of this sign is at least 100 feet downstream of the point at which the exit gore is 25 feet wide. The “Prepare to
Stop” sign should be installed downstream of the “Meter On” sign. A recommended placement of this sign is at least 400-600 feet downstream of the “Meter On” sign and at least 1000 feet upstream of the stop line.

2.5. Pavement Markings

Pavement markings usually consist of either paint, plastic, or raised pavement markers. Lane lines are needed to separate the metered lanes. There also may be HOV bypass lane markings which are discussed in the subsection below. All the pavement markings should conform to the guidelines set in the MUTCD – Chapter 3B “Pavement and Curb Markings”.

2.5.1. Stop Bar

Stop bars should be placed at a location that balances the acceleration and taper length needed downstream of the meter with the queue storage needed upstream of the meter. It is not advised to provide staggered stop bars. When use of the shoulder is permitted during ramp metering, the shoulder should be marked with a stop bar. The stop bar should extend the entire width of all metered lanes, and should have a width of 24 inches.

2.5.2. HOV Markings

Signing and striping for an HOV bypass lane is needed to clearly designate the preferential lane usage. The standard pavement marking for an HOV bypass lane is the elongated diamond symbol found in Section 3.6 of this manual. Solid white lines separating the HOV bypass lane from the general purpose lanes as well as the dashed extension lines are needed to prevent turning vehicles from entering the HOV bypass lane by mistake.


3.0 HOV/MANAGED LANE

This section addresses major design treatments for HOV/managed lanes and related support facilities commonly applied to these lane treatments. Also addressed are HOV bypass lanes associated with ramp meters.

3.1 Lane and Roadway Geometrics

Each type of HOV lane design has its own set of lane design features, ancillary access, traffic control conditions and options. Each general type of design, shown through typical sections and example applications, is briefly presented in this section. Designs include concurrent-flow lanes, reversible lanes and ramp meter HOV lane bypasses. Access features are described in Section 3.2; supporting facilities are presented in Section 3.3; and related treatments addressing enforcement, incident management and systemwide issues are presented in subsequent sections 3.4 through 3.8.

3.1.1 Concurrent-Flow Lanes

Concurrent-flow lanes operate in the same direction of travel as the adjacent lanes, and typically, one lane is provided in each direction. Where possible, full inside median shoulders and a buffer separation with the general purpose lanes is included. These lanes may be physically separated from adjacent lanes, or not separated (Figure 3-1).

Figure 3-1 Concurrent Flow Lanes

Non-separated, full-time

Non-separated, part-time

Barrier-separated

Buffer-separated
Some form of delineation is needed for any kind of concurrent-flow lane to differentiate it from adjacent lanes. The minimum separation needs to be a wider than standard pavement marking, according to the latest federal guidance. Each type of concurrent-flow lane is described in more detail in the next sections.

Non-separated Treatment
Where a buffer is not provided and the HOV/managed lane is opened to all traffic during off-peak periods, the treatment may not be separated and should appear as a general use lane. The minimum lateral clearance, or shy distance to a median barrier, should be at least two feet. Desirably, a full width (8 feet to 10 feet) inside shoulder is provided. Separation lane marking between the HOV and general purpose lanes must include a wider than standard skip stripe (eight inches or more) and diamonds placed in the centerline of the lane at regular intervals in accordance with the latest guidance contained in the MUTCD. Further pavement marking guidance is provided in section 3.6.

Buffer-separated Treatment
AASHTO’s latest guidance (Reference 1) recommends buffers for concurrent-flow lanes. Figure 3-4 shows typical sections for desirable and minimum conditions. A variety of design techniques exist for buffer separated lanes. The buffer width should nominally be four feet and no less than 1.5 feet. A much wider buffer width of six to eight feet may appear as a refuge for vehicle breakdowns where high speed traffic exposes the driver to a safety hazard on both sides. It is difficult to accommodate the requisite pavement markings in a buffer of less than 18 inches. A buffer separated lane may apply a conventional four-foot buffer and reduce the buffer area around such isolated restrictions as bridge columns for short distances. Ideally such conditions are appropriately facilitated by varying the inside shoulder width to keep the lane alignment straight through the impediment.

If continuous access is allowed, double skip stripes placed around and within the buffer area may be appropriate. If access is restricted, dual solid stripes are applied and broken wherever access is permitted (Figure 3-2).

Many candidate settings for concurrent flow lanes typically have many bridge and related impediments that make widening to full design standards extremely difficult. In such cases, careful study of the proper trade-offs for lane, shoulder and buffer widths are warranted. These conditions are herein referred to as minimum designs, which often involve the removal or reduction in existing inside breakdown shoulders and perhaps slight reductions in some lane widths for the added lane. While trade-offs in each case will vary depending on site conditions, Table 3-1 provides a reference of commonly applied priorities when trying to accommodate key design features in constrained settings.
Figure 3-2: Concurrent Flow Buffer Separated Cross Sections

Table 3-1 Suggested Design Sequence of Trade-offs for Concurrent-Flow HOV Lanes

<table>
<thead>
<tr>
<th>Suggested Sequence</th>
<th>Cross Section Design Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>Reduce HOV lane left lateral clearance to no less than 2 feet.</td>
</tr>
<tr>
<td>Second</td>
<td>Reduce freeway right lateral clearance (shoulder) from 10 feet to no less than 8 feet.</td>
</tr>
<tr>
<td>Third</td>
<td>Reduce buffer separation between HOV and general purpose lane to no less than 1.5 feet.</td>
</tr>
<tr>
<td>Fourth</td>
<td>Reduce HOV lane width to no less than 11 ft. (Some agencies prefer reversing the fourth and fifth trade-offs when buses or trucks are projected to use the managed lane. The buffer markings may encroach on the 11-foot width.).</td>
</tr>
<tr>
<td>Fifth</td>
<td>Reduce selected mixed-flow lane widths to no less than 11 feet. (Leave at least one 12-foot outside lane for trucks).</td>
</tr>
<tr>
<td>Sixth</td>
<td>Transition barrier shape at columns to vertical face, or remove buffer separation between the HOV lane and general purpose lanes.</td>
</tr>
</tbody>
</table>

Source: Reference 1.
Barrier-separated Treatment

A variety of lane treatments are separated by concrete barriers or pylons. The former is called a hard barrier; the latter is a soft barrier. Barrier-separation provides a more effective, controlled environment which can improve operational performance, enforcement and safety. However, barrier separation can consume more right-of-way and raise project costs because separate breakdown shoulders are needed for both traffic streams. Access is more restrictive. Pylon separation, in lieu of concrete barriers, may reduce cost but add to maintenance since pylons are more likely to be damaged and need replacement. Some form of barrier separation may be required for pricing concepts. Alternative barrier-separated typical sections for desirable and reduced design settings are shown in Figure 3-3.

Figure 3-3: Two-way Barrired HOV Facility Cross Sections

---

1 Operational treatments should be incorporated if the minimum design cross sections are used.
Access to barrier separated lanes may be via at-grade weave sections and openings in the barrier separating the concurrent roadways, or via two-way flyover ramps or local drop ramps with intersecting streets.

3.1.2 Reversible Lanes

Reversible lanes operate in the median and are separated from adjacent oncoming traffic by permanently placed barriers. Reversible designs can accommodate single or multiple travel lanes. A variety of cross sections are common to both. Figure 3-4 provides alternate cross sections for a single lane, and Figure 3-5 provides similar guidance for a multi-lane roadway. While lane widths are nominally 12 feet, options exist in a single lane setting for placing a full shoulder on one side, or placing a shy distance (half shoulder) of four feet on both sides. Some locales favor a split shoulder to discourage vehicles attempting to pass in the shoulder. The combination of lane, shoulder and shy distance should add up to at least 20 feet so that moving traffic can bypass a stalled vehicle. Barrier openings or gates for emergency vehicles may be needed at periodic intervals.

In a dual lane setting, a full shoulder is provided on one or both sides. A minimum shy distance to the barrier should be two feet.

Potential trade-offs in fitting reversible lanes into constrained roadway settings are provided in Table 3-2.

<table>
<thead>
<tr>
<th>Suggested Sequence</th>
<th>Cross Section Design Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>Reduce HOV envelope to 42 feet according to the highest level minimum envelope in Figure 3-5.</td>
</tr>
<tr>
<td>Second</td>
<td>Reduce freeway left shy distance to no less than 2 feet.</td>
</tr>
<tr>
<td>Third</td>
<td>Reduce freeway right side shoulders to 8 feet.</td>
</tr>
<tr>
<td>Fourth</td>
<td>Reduce HOV lane width to no less than 11 feet (some agencies prefer reversing the fourth and fifth trade-offs when buses and trucks are projected to use the HOV/managed lane).</td>
</tr>
<tr>
<td>Fifth</td>
<td>Reduced selected general purpose lane widths to no less than 11 feet.</td>
</tr>
<tr>
<td>Sixth</td>
<td>Convert barrier shape at columns to vertical face (Refer to Figure 3-8)</td>
</tr>
</tbody>
</table>

Source: Reference 1.
Figure 3-4: Reversible Single Lane Cross Sections

DESIRABLE

MINIMUM

MINIMUM

¹ Operational treatments should be incorporated if the minimum design cross sections are used.
Figure 3-5: Reversible Multiple Lane Cross Sections

Circumventing columns is most common for a reversible lane. Figure 3-6 shows how typical jersey barrier alignments are adjusted approaching bridge and sign columns.

Figure 3-6: Converting Barrier Shape to Vertical at Columns
A key design component of freeway reversible lanes is access and related traffic control equipment at each access location. Access may be made from the left or right side of a freeway via a flyover ramp, but in either case the access must be channelized, gated and signed to control the correct movement of traffic into and out of the reversible roadway. Typical access requirements include the following features:

- A single lane channelized with barriers to guide traffic into and out of the reversible roadway
- A series of gates and a catchment screen at each high speed entrance to thwart wrong way movements when the gate is closed
- Dynamic signing (at least one advance sign and one at the entrance) to indicate if the entrance is open or closed
- Lane controls (considered optional) to help communicate lane operating status
- Other traffic control devices, such as cones, pylons or dynamic signs to reinforce operating status of the ramp

For low speed entrances from a street or park & ride lot, a single gate and dynamic sign may suffice, and channelization may be via curb and gutter treatment.

### 3.1.3 Metered Ramp HOV Bypasses

HOV ramp meter bypasses are widely applied and represent the largest number of HOV lane treatments. Some metropolitan areas have up to 300 such sites where HOVs can bypass a metered ramp. HOV bypasses may be oriented to the left or right side of the meter. Specific orientations should consider the specific design setting and origins of HOVs upstream. California cities—San Diego, Bay Area and LA basin—exhibit a wide range of both left and right side oriented bypass lanes.

During design, consideration for a ramp meter bypass should be given to good sight distance, adequate lane delineation to preclude metered traffic from getting trapped, and adequate downstream merge distance. Example layouts are provided in Figure 3-7 for common ramp orientations. The bypass lane is commonly located to the right of entering ramp traffic, but may be oriented to the left if the predominate HOV traffic movements upstream are left turns. A downstream monitoring area on a right side shoulder for police enforcement is desirable. More detailed design guidance for metered ramp meter treatments is provided in Section 2.0.
3.2 ACCESS

This section reviews access treatments associated with mainline HOV/managed lanes. Access consideration is needed for any design. As a minimum, design consideration is needed for how a lane transitions to and from adjacent general purpose lanes. Access along a concurrent-flow lane may be allowed at any point, or access may be restricted. If access is restricted, designated access zones or direct access ramps will be needed. If a reversible or contraflow lane is designed, all access features will need to be through designated access ramps to control the direction of traffic.

3.2.1 Transition Treatments

HOV/managed lanes require special attention at the beginning and end of the project. Providing HOV/managed lanes that otherwise save time should not cause users to lose time where they terminate and merge back into general purpose lanes.
One recent study in Los Angeles found that a significant portion of the time saved along HOV lanes was being lost where temporary lane drops forced HOVs back into regular traffic, causing queues upstream of the project terminus for all motorists.

**Beginning an HOV Lane**

Since a majority of freeway oriented HOV lanes are located on the left side, next to the fast lane on most freeways, the beginning of these lanes should not typically change designation and cause general traffic to drive into a downstream restricted condition. HOV/managed lanes should desirably be added to the overall roadway cross section via a standard left side exit and signed as such (Figure 3-8).

![Figure 3-8: Beginning an HOV Lane](image)

Similarly, left side entrances are associated with reversible lanes where traffic enters the median or crosses over the median to enter the opposing side of the freeway.

**Terminating an HOV Lane**

Depending on anticipated volumes, downstream termination treatments may merge traffic back into other lanes (Figure 3-9). If demand is quite high, carry managed lane volumes into a free lane while dropping a general purpose lane further downstream on the right (Figure 3-10). Both origin and termination treatments locations need to consider proximity to existing or planned right-side freeway ramps. Experience suggests that for single lane treatments, providing 1000 feet of minimum lane weaving is desirable, with 700 to 800 feet being adequate in some instances. This determination is also illustrated in Figure 3-10. Locating a terminus should consider grade, curvature and specific traffic conditions. Tangent locations are encouraged where good sight distance can be provided. Each design setting is unique in terms of the traffic mix, lane demand, roadway geometrics and related factors. The termination treatment location and weave or merge section should also traffic impacts under differing peak and off peak travel conditions.
3.2.2 At-Grade Intermediate Access

For lane treatments that restrict access, the most common form of intermediate access treatment is application of a designated opening in the barrier, buffer or pavement marking that permits HOV vehicles to enter and exit. Most intermediate access for single concurrent-flow lanes allow both entry and exit movements within the same designated zone. A majority of concurrent-flow lanes with designated access apply ingress/egress zones as illustrated in Figure 3-11 and Figure 3-12. The length of the access zone may vary depending on the amount of accessing traffic, orientation on a curve or tangent, and proximity to right side entrance and exit ramps. As noted in Figure 3-10, locating intermediate access designs should avoid the creation of tight weave conditions between upstream and downstream right side ramps and a left side access zone. A minimum of 700 to 800 feet per lane weave from right to left, and vice versa, is recommended. Locating an access to allow 1000 feet of weaving per lane is desirable.
If high access volumes or multiple managed lanes are anticipated, best practice is to separate ingress and egress movements into separate zones or provide a weave lane (auxiliary lane) between the parallel roadways. Both design approaches are illustrated Figure 3-13. An example layout incorporating a weave lane for a barrier-separated roadway is shown in Figure 3-14. Incorporating weave lanes to address the speed differential between each roadway may still adversely affect the operation of one or both roadways. Grade-separated flyover ramps (Section 3.2.4) may be more appropriate for high volumes where weaving problems are anticipated.
For reversible lanes, any at-grade access must be channelized through the separation barrier with proper gating and signing (Figure 3-15). Otherwise, access must be grade separated over the general purpose lanes, either as drop ramps or flyover ramps (see Section 3.2.4).
3.2.3 Direct Access-Local Drop Ramps

Local access treatments to major streets and transit facilities such as park & ride lots and transit centers are facilitated by use of a grade separated drop ramp. Such ramps are typically oriented within the median with left side entrance and exit ramps to the HOV or managed lanes (Figure 3-16). They may be oriented in one or both freeway directions.

*Figure 3-16: Example Two-Way Drop Ramps with Concurrent Flow Lanes*

Drop ramps always connect to a low speed roadway that may involve a traffic signal or other traffic control device at the ramp terminus. Accordingly, drop ramps require careful consideration in their design to take into account the sight distance that leads traffic from a high speed to low speed condition in a short distance, and vice versa. Drop ramps on current flow lanes are typically two-way, with a barrier that transitions to an open buffer or curb section between opposing directions. An example layout is provided in Figure 3-17.
Reversible lanes can also have drop ramps located to the left or right side of the reversible roadway (Figure 3-18). The greatest safety issue with a reversible drop ramp is gating and signing the roadway such that the design can address potential wrong way movements. Two strategies for accomplishing this is either channelizing the ramp terminus with gating to remove the likelihood of wrong way movements, or to install a gate that is traffic actuated.

Figure 3-18: Example Layout for a Reversible Drop Ramp
A wide variety of drop ramp examples exist in Seattle, Houston, Atlanta, Hartford, Denver, Northern Virginia, Phoenix, Salt Lake City, and southern and northern California.

3.2.4 Direct Access-Flyover Ramps

In locations where high HOV/managed lane volumes are anticipated for connecting traffic between two freeway HOV/managed lane facilities or with major transit or activity centers, high-speed flyover ramps are justified. For concurrent-flow facilities, ramps typically serve both directions. Flyover ramps are designed to the same geometric and design speed conditions as any other higher speed freeway-to-freeway connector. By sharing a common structure, ramps are most commonly oriented to the left of the mainline HOV/managed lane roadway and connect two freeway HOV lanes left to left. (Figure 3-19). Two-way flyover ramps contain barrier separation between opposing flow directions. The cross section on the ramp is the same as a two-way barrier separated HOV facility. Examples of two-way flyover ramps are shown in Figure 3-20.

Figure 3-19: Example Layout for a Two-way Flyover Ramp
Flyover ramps represent a significant investment, and can only serve selected high-volume movements within an all-directional interchange as noted in the previous figure. Where demand exists for multiple movements, another flyover ramp approach is to attach a median oriented ramp to existing freeway interchange connectors. This approach is illustrated in Figure 3-21.

For reversible facilities, the ramps are similarly reversible. Examples of both two-way and reversible flyover ramps are shown in Figure 3-22.
Flyover ramps are also a way of terminating a HOV or managed lane facility. One such example from a reversible lane is provided in Figure 3-23. Terminating a facility with flyovers, particularly for reversible lanes, allows better gating and control of traffic from the right side, and may allow access to major freeway ramps for better distribution of traffic and reduced weaving.

Figure 3-23: Terminating a HOV Facility with Flyover Ramps

3.2.5 Summary of Access Options

A comparative summary of the attributes for each type of access is shown in Table 3-3.

3.2.6 Right Side Oriented Lanes

Few HOV lanes are oriented outside the medians of freeways. HOV and managed lanes are intended to serve long distance and express trip commuters. However, situations have arisen where for particular transit needs where bus routings either use a freeway for a short distance or where transit stations and stops are located along the freeway, this
Table 3-3: Summary of Access Options

**At-Grade Slip Ramp at Project Termination**
- An effective way of feeding and distributing high lane volumes with the adjacent freeway.
- Requires left-hand entry/exit with the freeway.
- Can be designed as a safe and enforceable treatment.
- Low cost; easily modified if HOV lane facility is extended.
- Used as a typical termination treatment on most projects.

**At-Grade Slip Ramp as an Intermediate Access**
- Lowest-cost intermediate access approach; can be easily modified (relocated or removed).
- Most compatible with restricted envelopes; requires little widening.
- High accessing volumes should include parallel weave lane.
- High-volume conditions can increase conflict points; can disrupt the adjacent freeway or HOV lane level of service.
- Enforcement is difficult.
- Location is critical; if too close to nearby freeway intersections, weaving conflicts across the freeway increase.

**Drop Ramp with a Street**
- An effective way of collecting and distributing all mixes of HOVs, as well as serving park-and-ride or off-line transit facilities.
- Provides opportunities to control or enforce entering volumes.
- Works for reversible-flow or two-way configurations.
- Best if not considered at an existing intersection with freeway access.

**Drop Ramp to a Park-and-Ride Lot or Off-Line Bus Transit Station**
- Effective way of extending an HOV facility into an off-line support facility, thereby increasing travel time savings.
- Not recommended for serving other HOVs which have no affinity for the support facility; requires circulation consideration within the support facility.
- Generally requires high transit and/or rideshare volumes to be cost effective.
- Works best for two-way operations, although can be workable for reversible-flow if drop ramp movements are reversed as well.

**Flyover Ramp**
- Highest-speed design, intended for high interfacing volumes; most closely approximates other freeway ramp in design speed.
- Serves all HOV lane users well.
- Can be applicable as an intermediate access or termination treatment.
- Can be cost-prohibitive as a means of accessing support facilities.
- Least flexible treatment; sometimes overlooked on an interim HOV lane operation and added later as demand warrants.
- Equally appropriate for two-way or reversible-flow operations.
orientation does not work. For such needs, buses weaving across the freeway for short distances poses operational and safety risks, and a right side, or shoulder bus lane, may be appropriate. Right side bus lane examples on freeways are few, and operational experience suggests that they work best when both the bus volumes and entering and exiting volumes on the freeway are quite low. They may work for carpools if the occupancy requirements are set at 3+ so that demand will not cause conflicts with on- and off-ramps. There may be prerequisite conditions placed on right side HOV lane users as well. For example, the Minneapolis-St. Paul area allows buses to travel on some freeway shoulders whenever freeway speeds drop below a specific threshold during prescribed peak periods, and buses are restricted to a commensurately lower speed as well when driving the shoulders. Figures 3-24 and 3-25 provide an illustrated examples and design guidance for right side shoulder bus lane treatments, based on information developed in Washington on several right side HOV lanes that they have implemented. Right side HOV lanes on freeways and expressways are more common in Canada and other countries outside the U.S.

Figure 3-24: Examples of Right Side HOV Lanes Operated on Shoulder

3.3 SUPPORT FACILITIES

3.3.1 Enforcement Considerations

Enforcement is critical to the successful operation of any HOV/managed lane facility. The role of an HOV lane enforcement program is to ensure that operating requirements, including vehicle-occupancy levels, are maintained to protect travel benefits, to discourage unauthorized vehicles, and to maintain a safe operating environment. Visible and effective enforcement promotes fairness and maintains the integrity of the facility to help gain and maintain public acceptance of the project.
Figure 3-25: Example of Right Side HOV Lane Design Guidance at Ramp Junctions

Outside (Right) HOV Lane Typical On-Connection

Outside (Right) HOV Lane Typical Off-Connection

*May be reduced for speed limits of 45 MPH or less.

Source: Washington State Dept. of Transportation, I-405 project data.

Not To Scale
Enforcement policies and programs perform a number of important roles. First, their development will help ensure that all of the appropriate agencies are involved in the process and that all groups have a common understanding of the project and the need for enforcement. Thus, participation is critical of representatives from enforcement agencies, state and local judicial systems, the state department of transportation, the transit agency, local municipalities, the metropolitan planning organization, the rideshare agency, federal agencies including the Federal Highway Administration and the Federal Transit Administration, and other groups throughout the development and implementation of enforcement policies and programs. Second, this same information can be provided to the public, especially travelers in the corridor, to help introduce the HOV facilities and to communicate the guidelines for use of the lanes. Third, the enforcement policies and programs should be followed to maintain the integrity of the facility by deterring possible violators and to promote the safe and efficient use of the lane.

HOV enforcement is seldom dedicated to this facility alone. Police typically perform a variety of services on the freeway system, and HOV enforcement often competes with these other, often more critical activities, such as incident response. Designs need to provide for ease and convenience of enforcement, or police will not perform this activity. One of the most critical elements to performing enforcement is providing safe enforcement areas within the roadway design. Figure 3-26 shows an example of a project that does not have adequate space to stop and cite a violator.

Figure 3-26: Police Enforcement on a Restricted Width HOV Lane

Design of Enforcement Areas

HOV lanes should be designed so that they can be safely and efficiently enforced. The safety of both police personnel and travelers in the HOV lane and the general-purpose lanes should be considerations in the design process. In addition, local or state laws regarding how enforcement policies and practices should be considered with enforcement agency input. Project success is jeopardized by enforcement areas or provisions that will not be used by the respective police.

Some lane treatments such as reversible lanes are relatively easy to enforce because of the limited ingress and egress opportunities. Other design treatments are much harder
because they share common pavement with other traffic. Table 3-4 highlights some of the attributes associated with HOV lane enforcement strategies that have been successful in some areas. Barrier-separated lanes are generally considered to be easier to enforce than non-separated facilities because of the limited and controlled access they provide.

Table 3-4: Enforcement Attributes Associated with Different HOV Facilities

<table>
<thead>
<tr>
<th>Type of HOV Lane Facility</th>
<th>Preferred Enforcement Attributes</th>
<th>Minimum Enforcement Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concurrent Flow Barrier</td>
<td>• Enforcement areas at entrances and exits</td>
<td>• Enforcement areas at entrances or exits</td>
</tr>
<tr>
<td>Separated: Two-way and Reversible</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concurrent Flow</td>
<td>• Continuous enforcement shoulders with periodic barrier offsets</td>
<td>• Periodic mainline enforcement areas</td>
</tr>
<tr>
<td></td>
<td>• Continuous right-side shoulders</td>
<td>• Monitoring areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Continuous right-side shoulders</td>
</tr>
<tr>
<td>Contraflow</td>
<td>• Enforcement area at entrance</td>
<td>• Enforcement area at entrance</td>
</tr>
<tr>
<td></td>
<td>• Continuous shoulder for enforcement</td>
<td></td>
</tr>
<tr>
<td>Queue Bypass Treatments</td>
<td>• Enforcement area on right-side shoulder</td>
<td>• Enforcement monitoring pad with continuous right-side shoulder downstream</td>
</tr>
<tr>
<td></td>
<td>• Continuous right-side shoulder</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Duplicate signal head facing enforcement area</td>
<td></td>
</tr>
</tbody>
</table>

The term enforcement area refers to a number of potential design treatments that provide dedicated space for police personnel to monitor an HOV lane facility, to pursue and apprehend a violator and issue a ticket or a citation within the dedicated area. For concurrent-flow lanes, a typical layout for a median enforcement area is shown in Figure 3-27 and examples in Figure 3-28. Shoulder space adjacent to an HOV lane is required for these functions. The enforcement requirements should be coordinated with the enforcement personnel early in the design process so that local perspectives on enforcement strategies can be incorporated. This permits police to become familiar with the project, to anticipate any additional requirements or revisions in initial concepts, and make suggestions for the design that may make enforcement simpler, safer, more efficient and compliant with local laws. The primary type of infraction that enforcement officers confront is occupancy violations, which requires them to see inside a vehicle and to be able to count the number of occupants. Good lighting and a safe vantage point (to see inside vehicles) are needed to perform these enforcement functions. Enforcement areas should not be placed under bridges to ensure the safety of enforcement personnel.
Police may choose to monitor traffic by parking in the enforcement area and accelerating to enter the lane and enforce further downstream. Or they may prefer to park and wave violators over into the median enforcement area. The length in the layout allows for violators to be stopped and be able to accelerate back to merge into traffic safely. Another approach is to provide continuous full-width median shoulders along the project. This can offer a more flexible way of handling enforcement activities.

A variety of enforcement practices may be used on a HOV/managed lane. The design of enforcement areas should be flexible to account for a variety of enforcement strategies.
On barrier-separated facilities such as reversible lanes, enforcement actions can be performed near the entrance or exit ramps where traffic is often moving more slowly or along the lane in the shoulders (Figure 3-29). If located near a slow-speed entrance or exit ramp, the area may be a designated parking pad located on one side of the ramp, or in the unused portion of the ramp if it operates reversible flow. The enforcement area can serve as both a monitoring and an apprehension site. Examples are provided in Figure 3-30. There are no prescribed layouts for these locations, but good sight distance and illumination are important considerations.

**Figure 3-29: Potential Locations for Low-speed Enforcement Areas**

![Figure 3-29: Potential Locations for Low-speed Enforcement Areas](image1)

**Figure 3-30: Designated Enforcement Areas on a Ramp**

![Figure 3-30: Designated Enforcement Areas on a Ramp](image2)
For non-separated lanes, enforcement may occur anywhere if a continuous shoulder is provided. In more restrictive settings, enforcement areas may allow officers to monitor traffic with the apprehension of violators occurring at a downstream location. This location may be another enforcement area or a wide left or right shoulder.

3.3.2 Transit Stations-On-Line

Transit facilities often accompany HOV lanes. The most common forms of transit treatment include stations and parking lots. Stations are either constructed separate from the freeway as “off-line” stations and may be connected through a drop ramp or flyover ramp; or stations may be constructed “on-line” in the freeway median straddling the HOV/managed lane facility. This section addresses on-line stations and general design considerations for transit facilities. Subsequent Sections 3.3.4 and 3.3.5 address parking facilities.

Bus platforms are the most common application for any type of station. Functional requirements for bus loading areas at platforms are illustrated in Figure 3-31.

On-line stations may be implemented in a variety of ways. They may be designed in the median, requiring the freeway to be widened around them. Figure 3-32 illustrates the different configurations for median on-line stations. In all configurations, the main HOV/managed lane roadway operates around the station on separate, high-speed through lanes. The station area is protected by concrete barrier or walls. Its orientation may have side or center platforms. If a side platform orientation is preferred, bus doors will align the platform for the respective travel direction, but a wider design envelope will be required to account for the dual platforms, shy distances and shoulders (Figure 3-33). If a center platform is considered, then bus movements will have to criss-cross paths at the ends of each platform in order for the doors to align. For this reason, center platforms are not typically recommended as errant vehicles can get into the bus ramps traveling the wrong direction. Both designs will require significant width and length, often characterized as impacting about ¼ of a mile of freeway for the necessary tapers or transitions on either end. Median on-line stations also require grade-separated pedestrian access, with commensurate accommodation for handicapped passengers via elevators or escalators. The respective cost for an on-line station can be quite high, and accordingly, other transit facility strategies including consideration of drop ramps or moving transfer functions to off-line facilities is typically more cost-effective.

The on-line station may be designed as part of a drop ramp to an intersecting street or pedestrian overcrossing, with the functional attributes of the platforms overhanging the freeway (Figure 3-34). The drop ramp approach requires less freeway widening since the platforms can overhang the freeway below. Both design approaches have limited examples nationally. Several examples of stations along the I-110 Harbor Transitway in Los Angeles are shown in Figure 3-35.
Figure 3-31: Bus Loading Area Dimensions

IN-LINE PLATFORM
NORMAL BERTH

IN-LINE PLATFORM
MINIMUM BERTH

SHALLOW SAWTOOTH PLATFORM

* BUS POSITIONS DEPENDENT ON ARRIVAL SEQUENCE. IF INDEPENDENT PULLOUTS DESIRED, INCREASE ROADWAY WIDTH TO 22 FT. MIN. AND ADD 11 FT. TO BERTH LENGTH.

<table>
<thead>
<tr>
<th>Single Unit</th>
<th>Articulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus</td>
<td>Bus</td>
</tr>
<tr>
<td>40'</td>
<td>60'</td>
</tr>
<tr>
<td>80'</td>
<td>100'</td>
</tr>
<tr>
<td>45'</td>
<td>65'</td>
</tr>
<tr>
<td>65'</td>
<td>85'</td>
</tr>
</tbody>
</table>
Figure 3-32: On-line Station Platform Configurations

CENTER PLATFORM

REGULAR TWO-WAY FLOW (CROSS-OVER REQUIRED)

PEDESTRIAN ACCESS

BYPASS LANE

BUS LOADING LANE

PLATFORM

BUS LOADING LANE

BYPASS LANE

STAIRS/ESCALATOR

NOT TO SCALE

Example: Downtown Station, I-10, Phoenix, AZ.

REVERSE "ENGLISH STYLE" FLOW

PEDESTRIAN ACCESS

BYPASS LANE

BUS LOADING LANE

PLATFORM

BUS LOADING LANE

BYPASS LANE

STAIRS/ESCALATOR

NOT TO SCALE

Example: Hospital Station, I-10, Los Angeles, CA.

SIDE PLATFORM

PLATFORM

BUS LOADING LANE

BUS LOADING LANE

PLATFORM

PEDESTRIAN ACCESS

NOT TO SCALE

Example: East Busway Stations, Pittsburgh, PA.
Figure 3-33: On-line Station Platform Widths

SIDE PLATFORM - MINIMUM

SIDE PLATFORM - DESirable (MIXED HOV OPERATION POSSIBLE)

CENTER PLATFORM - MINIMUM

CENTER PLATFORM - DESirable (MIXED HOV OPERATION POSSIBLE)
Figure 3-34: On-line Station on a Drop Ramp

Note: Bus platforms can be near side or far side oriented at the ramp intersection.
3.3.3 Park & Pool Lots

Small parking lots used for vanpool and carpool staging are often located in excess right-of-way near local freeway interchanges. These lots may only need to have 10 to 30 spaces. They are not intended for regularly scheduled transit service. Designated signing should indicate that the parking area is for use by carpooling only, and no overnight parking is permitted. Park & pool lots are very useful to augment an HOV lane, particularly if lots are provided eight or more miles from major employment areas. Figure 3-36 illustrates an example of a park & pool lot. Typical design guidance for parking lots layout and space dimensions is provided in Figure 3-37.

Figure 3-36: Example Park & Pool Lot
Figure 3-37: Typical Parking Lot Layout Design Criteria

Typical Stall Layout - 45°
Standard Cars & Small Cars

Typical Stall Layout - 90°
Standard Cars

Typical Stall Layout - 90°
Small Cars

Typical Parking Dimensions, AASHTO

<table>
<thead>
<tr>
<th>Type of Automobile</th>
<th>Stall Width (feet)</th>
<th>Stall Length (feet)</th>
<th>Isle Width (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>8.5-9.5</td>
<td>18-20</td>
<td>24-26</td>
</tr>
<tr>
<td>Compact</td>
<td>7.5-8.5</td>
<td>15-17</td>
<td>20-22</td>
</tr>
</tbody>
</table>
3.3.4 Park & Ride Lots

Larger lots intended for regularly scheduled transit service are termed park & ride lots. These lots are typically 500-1000 space facilities located 5 to 8 miles or more from major employment centers. They are serviced by express transit routes and are sized to best intercept commuters from major residential markets. Park & ride lots are best located within ¼ mile from the freeway with good access for transit to the HOV lane. Drop ramps may be designed into the lots of they are within close proximity to the freeway. Figures 3-38 and 3-39 provide example layouts for a medium and large sized park & ride lot, respectively. In most cases, separating bus access from parking users helps improve traffic flow and transit service reliability. Examples of park & ride lots with direct drop ramp access to freeway HOV lanes are shown in Figure 3-40.

Figure 3-38: Prototype Layout for a Medium Park & Ride Lot
Figure 3-39: Prototype Layout for a Large Park & Ride Lot

Figure 3-40: Park & Ride Lots with Direct Access
3.4 Traffic Controls and ITS

A wide variety of ITS applications can be considered for HOV/managed lanes. These relate to real time monitoring of day-to-day operation, enforcement, incident management, BRT and transit related applications for passenger information, system integration with general purpose lane needs and HOV/managed lane performance monitoring. Described in this section are design issues unique to the operation of HOV/managed lanes, including pricing, access control, and incident management and communication.

3.4.1 Incident Management

A strategy that responds to minor incidents, crashes and other non-recurring events that disrupt traffic, whether they be freeway- or HOV-related, is called incident management. The goal of incident management on HOV/managed lanes is similar to all freeway lanes--to react and clear incidents and other capacity-restricting events in a minimum amount of time to maintain overall roadway reliability. Four elements involved in incident management include:

- Detecting the incident
- Responding to the incident
- Clearing the incident, and
- Communicating this information to other motorists.

Detection

Verifying the type, nature, and location of an incident involves detection, which can come from witnesses calling in on cell phones, radio dispatches from police, television monitoring, or roadside or pavement detectors monitoring traffic flow. Still, these tools may not be sufficient to provide an effective and reliable means of knowing where the incident is, how significant it is, and what response will be required. Newer technologies are continuing to emerge, like GPS-based communication, and may further enhance detection capability.

Response

Responding to an incident involves various methods to resolve a disruption. Traditional means of removing disabled vehicles generally work for non-separated or buffer-separated concurrent flow lanes, but may not work for reversible or barrier separated lanes because of the restricted access roadway setting. A typical response involves the deployment of a tow truck to remove the disabled vehicle. This response may require special agreements with local tow truck companies, or with local or state agency towing operators. Whenever a major incident disrupts all freeway and HOV lanes and barriers do not preclude traffic from using all lanes, emergency and traffic management personnel may allow all traffic into an HOV lane for the affected period to help clear the scene. Announcement of this temporary access can occur via radio and changeable message signs, and such policy exists for HOV lanes in other regions.
Responsiveness is enhanced for barrier-separated lanes if openings in the barrier or barrier opening gates are included at periodic intervals of one to two miles, depending on frequency of other direct access features. Examples of both are illustrated in Figure 3-41.

**Figure 3-41: Examples of Emergency Barrier Openings**

![Examples of Emergency Barrier Openings](image)

**Clearing**

Clearing an incident involves the removal of the impediments, usually the disabled or damaged vehicles, using the same methods on HOV lanes as are used on freeways in general. The inclusion of a breakdown shoulder adjacent to the HOV lane can be helpful in providing refuge for a disabled vehicle and a means for emergency personnel to quickly access the scene of an accident and clear it more quickly. Barrier-separation can help keep incidents in one facility from affecting the parallel roadway, but may inhibit emergency vehicle and wrecker access without the presence of emergency barrier openings. Lane treatments with less than 20-foot overall widths between barriers may be particularly vulnerable to incidents that are difficult to clear, because the width will severely limit how fast wreckers can clear the incident.

**Communication**

Conveying real-time information to HOV/managed lane users involves many communication channels, best facilitated from a single command center. Communication to lane users is best provided in advance of ingress locations, so that if the facility needs to be closed, users can choose other routes before becoming committed. On reversible-flow HOV facilities, communication needed to verify the direction of operation can also double as a means of providing incident management communication.

The above common steps may have different applications for each type of facility. For example, a much more intensive monitoring function is needed for a reversible or contraflow lane where wrong way movements need to be quickly detected and preferably intervened to avoid potential crashes. Similarly, a roadway design that does not contain a full emergency breakdown shoulder will experience a higher rate of failure where minor incidents can disrupt flow than a full design, and it will need more attention to monitoring and incident response countermeasures. While barriers separating the HOV/managed lane from other lanes may promote safer operation, the ease of addressing incidents may
be made more difficult. Without barriers any major incident may disrupt all traffic—
HOV and general purpose—in a given direction. Specific strategies applied to each
project setting are unique and often adjusted based on experience. In every case, more
aggressive monitoring and response to incidents is justified, and users will typically
respond if the level of reliability is inadequate. Many of the more constrained and highly
utilized projects employ on-site personnel and services that can provide a high degree of
responsiveness to any events (operational or maintenance related) that can disrupt or
compromise the intended operational integrity of the HOV or managed lane facility.
Where possible, these functions are monitored remotely and coordinated with field
personnel. Signing may target specific information to HOV lane users (Figure 3-42).

Figure 3-42: Communication to of Real-time Information to HOV Lane Users

![Restricted Lane Info Sign](Image)

3.4.2 Incident Management and Communication

The functional requirements for managed roadways are best integrated into a region’s
traffic operation center. In many cases, on-site personnel are also employed to monitor
and address traffic incidents and enforce rules and regulations that cannot be addressed
remotely. Reversible flow lanes, in particular, must have on-site staffing to ensure safe
and efficient opening and closure of lane operation, regardless of the level of automation
applied to the deployment of traffic control devices. Typically, staffing varies of the
degree of automation, but a minimum of one person per peak period needs to drive the
lane and make sure all of the traffic control devices are fully deployed in a correct
manner.

Managed lanes are increasingly turning to ITS systems to track users, monitor operation
performance, confirm whether tolls have been paid, and confirm lane status when
incidents occur. Website posting of separate real-time travel speeds and service
reliability for the HOV lanes in some cities such as Seattle, Houston and Orange County,
California, are already occurring, enabling users to quickly assess available travel
benefits between the parallel roadways. Functional requirements for the freeway and
HOV/managed lane system should be reviewed periodically as design upgrades in
technology and traffic operations management allow.
3.5 Signing

The 2003 edition of the MUTCD contains new guidance for regulatory and guide signing for the most common concurrent-flow HOV lane applications on freeways. Additional requirements for the placement of signing are also included. The most common types of access treatments are included as examples. This guidance recommends signing that is consistent with regulatory and guide signing principles applied to freeways for access restricted lane designs, including advance exit information. While signing has generally been consistent nationally among projects, considerable variation exists for pavement markings. This section covers general guidance for HOV lanes.

Specific MUTCD sections addressing preferential and HOV signing are Section 2E.59 and Sections 2B.26 through 2B.28 for preferential lane signs (R3-10 through R3-15).

3.5.1 HOV Signing

HOV signing has typically addressed HOV lane regulations. Only recently has guide signing been added due to the number of projects that regulate access. The MUTCD has a section on regulatory requirements for restricted lane signing since the 1970s, but more recently greater guidance has been included to address both generic and specific guide sign conditions.

All regulatory signing found in the MUTCD Section 2B.26 should be black on white. Diamond symbols should appear on the top banner or upper left hand corner on each sign. Typical signing examples from the MUTCD are shown in Figure 3-43.

Regulatory signing related to occupancy requirements and hours of operation (if less than full time) need to be posted at frequent intervals of not less than ¼ mile. Typically, regulatory information can be ground mounted along the median barrier. Messages may alternate such that one sign defines what an HOV is, and the other provides the restriction. A third alternating sign may post hours of operation. Various examples are provided in Figure 3-44.

Aside from occupancy and operation restrictions, other applications of regulatory signing includes allowance for motorcycles and hybrid vehicles, exclusion of large trucks, buffer crossing and emergency shoulder use.

Barrier-separated signing needs to include greater use of overhead mounted signs, particularly at designated access locations. Buffer-separated lanes may apply more median barrier mounted signage, particularly for regulatory information.

Posting of standard advisory and regulatory roadway signing conditions should be on a sign panel background with a diamond in the upper left, to ensure the sign communicates only to the HOV/managed lane users (Figure 3-45).
Figure 3-43: Example HOV Lane Regulatory Signing from the MUTCD
(Figure 2B-7 in the 2003 MUTCD)

Ground-Mounted Preferential Only Lane Signs

- R3-10: HOV 2+ ONLY 2 OR MORE PERSONS PER VEHICLE
- R3-10a: BUS LANE AHEAD
- R3-10b: INHERENTLY LOW EMISSION VEHICLES ALLOWED
- R3-11: HOV 2+ ONLY 6AM - 9AM MON - FRI
- R3-11a: LEFT LANE
- R3-11b: BUSES ONLY 9AM - 9AM MON - FRI
- R3-11c: HOV 2+ ONLY 24 HOURS
- R3-12: HOV LANE AHEAD
- R3-12a: HOV LANE ENDS
- R3-12b: HOV LANE ENDS 1/2 MILE

Overhead Preferential Only Lane Signs

- R3-13: HOV 2+ ONLY 2 OR MORE PERSONS PER VEHICLE
- R3-13a: HOV 2+ ONLY 6AM - 9AM MON - FRI
- R3-14: HOV 2+ ONLY 6AM - 9AM MON - FRI
- R3-14a: HOV 2+ ONLY 6:30AM - 9:30AM MON - FRI
- R3-14b: BUS & TAXI ONLY 6AM - 9AM MON - FRI
- R3-15: HOV LANE AHEAD
- R3-15a: HOV LANE ENDS

Notes:
- The diamond symbol may be used instead of the word message HOV.
- The minimum vehicle occupancy requirement may vary for each HOV lane facility (such as 2+, 3+).
- The occupancy requirement may be added to the first line of the R3-12a, R3-15 and R3-15a signs.
- Some of the legends shown on these signs are for example purposes only. The specific legend for a particular application should be based upon local conditions, ordinances and Nevada State statutes.
Guide signing should match freeway standards and to the extent possible be mounted overhead if access to the HOV lanes is restricted. Examples of guide signing are provided in Figure 3-46.
3.5.2 Managed Lane Signing

Managed lane signing requirements are currently being researched and developed and will be included in a subsequent edition of the MUTCD. Signing typology follows standard freeway guide signing, with emphasis on the need for redundancy and advance access information. Such signing is appropriate whether the roadway is buffer- or barrier-separated, so long as access is restricted to designated locations.
Various challenges are faced for managed lane signing. Due to the dynamic nature of an operation that may change hour by hour with different pricing, user restrictions and access controls, the signing design must confront an array of operational possibilities, some of which may not be determined or confronted on opening day. Flexibility in signing design is the key to providing the greatest potential for controlling managed lanes through typical demand conditions as well as special events and incidents. This suggests that updated information should be communicated through the use of dynamic message signs (DMS). DMS elements to static signs may be appropriate, or for ultimate flexibility, the entire panel may be dynamic. Messages should be presented in ways to minimize the number of lines and yet be understandable.

The magnitude of regulatory and guide signing needs to be targeted to the greatest needs. A hierarchy of needs may be required because the conventions of signing a high-speed lane or roadway, coupled with dynamic operation rules, could overwhelm the physical space and drivers’ ability to absorb information. Where possible, regulatory and guidance information should be combined on the same sign structure or panel as examples illustrate, with the likelihood that some elements of the sign will be fixed and some may be dynamic. This condition is most apparent at access locations where managed lane signing on the left side of the roadway may compete with standard local ramp exit signing on the right.

### 3.6 Pavement Markings

The 2003 MUTCD reserves the use of the preferential lane diamond signs and pavement markings for HOV/managed lanes. Section 3B.23 of the MUTCD covers preferential lane longitudinal markings. Pavement markings need to be wider than traditional pavement stripes separating the HOV/managed lane from general purpose lanes. Options exist for a wider stripe, or use of multiple parallel stripes (i.e., for use in delineating a buffer area) to accommodate this requirement. A buffer is recommended for any concurrent flow lane treatment, even if the buffer is a wider than standard solid or standard skip stripe. Typical pavement markings from the MUTCD are illustrated in Figure 3-47.

Lane markings will vary depending on the intended HOV/managed lane design and operation. Listed in Table 3-5 are recommended pavement markings for different types of NDOT HOV and managed lane facilities.
Figure 3-47: Example HOV Lane Permanent Pavement Markings
(Figure 3B-26 from the MUTCD)

- a - Physically separated permanent lane(s)
- b - Full-time concurrent lane(s) where enter/exit movements are PROHIBITED
- c - Concurrent lane(s) where enter/exit movements are DISCOURAGED

Legend:
- ➡️ Direction of travel
- ★★ Applicable symbol or word

Note: Double yellow if centerline of 2-way roadway

Note: Some states and locales vary from these guidelines for local reasons.
Figure 3-47: Example HOV Lane Permanent Pavement Markings (Continued)
(Figure 3B-26 from the MUTCD)

d - Full-time concurrent lane(s) where enter/exit movements are PERMITTED

e - Right Side Concurrent Lane(s)

SINGLE BROKEN WIDE WHITE

DOUBLE SOLID WIDE WHITE (Crossing Prohibited)

WHITE EDGE LINE IF WARRANTED

LIMITED ACCESS EXIT SIDE STREET OR COMMERCIAL ENTRANCE

SINGLE BROKEN WIDE WHITE or SINGLE DOTTED NORMAL WHITE (Crossing Permitted)

SINGLE SOLID WIDE WHITE (Crossing Discouraged)

Note: Double yellow if centerline of 2-way roadway

Legend

→ Direction of travel

** Applicable symbol or word
Table 3-5 Recommended Pavement Markings

<table>
<thead>
<tr>
<th>Design</th>
<th>Operation</th>
<th>Access</th>
<th>Pavement Marking</th>
<th>Right side</th>
<th>Left side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concurrent-flow, concrete barrier</td>
<td>Full time</td>
<td>Restricted</td>
<td>Solid white 6”</td>
<td>Solid yellow 6”</td>
<td></td>
</tr>
<tr>
<td>Concurrent-flow, with channelizers</td>
<td>Full time</td>
<td>Restricted</td>
<td>Double solid white 6” defining buffer</td>
<td>Solid yellow 6”</td>
<td></td>
</tr>
<tr>
<td>Concurrent-flow, buffer separated</td>
<td>Full time</td>
<td>Restricted</td>
<td>Double solid white 6” defining buffer</td>
<td>Solid yellow 6”</td>
<td></td>
</tr>
<tr>
<td>Concurrent-flow, buffer separated</td>
<td>Full time</td>
<td>Continuous</td>
<td>Double solid white 6” defining buffer</td>
<td>Solid yellow 6”</td>
<td></td>
</tr>
<tr>
<td>Concurrent-flow, buffer separated</td>
<td>Part time</td>
<td>Continuous</td>
<td>Double skip stripe white 6” defining buffer</td>
<td>Solid yellow 6”</td>
<td></td>
</tr>
<tr>
<td>Concurrent-flow, Non-separated</td>
<td>Full time</td>
<td>Continuous</td>
<td>Solid white 8” or wider</td>
<td>Solid yellow 6”</td>
<td></td>
</tr>
<tr>
<td>Reversible flow</td>
<td>Directional</td>
<td>Restricted</td>
<td>Solid white 6”</td>
<td>Solid white 6”</td>
<td></td>
</tr>
</tbody>
</table>

* Based on HOV travel direction which is opposite of freeway direction.

The standard pavement marking used to delineate any form of preferential lane (HOV or managed lane) is a diamond placed on the pavement at regular intervals. The interval may relate to the application. Mainlanes typically require placement every 1000 to 2000 feet. Ramp spacing may be closer. All designated preferential lanes should include this diamond, in accordance with the MUTCD. Specifications are provided in Figure 3-48.

3.7 Pricing

Pricing is being applied to several freeway HOV facilities nationally and is planned for most managed lanes being planned and implemented. While current experience is limited, the following guidance is provided to accommodate electronic toll collection (ETC) to managed lanes. Specific design treatments for pricing management relate to the need to substantially segregate managed lanes from adjacent free lanes, provide communication to toll users, and enforce and administer the tolling process. While many options exist to address these needs, demonstrations implemented through the 1990s suggest that the most appropriate options involve the following design features:

- Separation of the HOV lane by concrete barriers, traffic pylons, or channelizers, with limited access. Open, unrestricted access has yet to be successfully demonstrated without a need for very frequent toll reading installations.
- Toll collection performed at one or a limited number locations along the managed lanes
- Enforcement considerations for occupancy, toll and ingress/egress violations
- Signing located upstream of the entrance ramps to communicate the toll and its related benefits
- An off-site facility or service that handles toll collection and administration

Each of these topics is discussed in this section.
3.7.1 Separation Treatments for Pricing

Pricing adds a new dimension to how HOV lanes are managed and enforced. The simplest approach to pricing is to operate a single tolling and enforcement site for the HOV facility. But this approach requires that the HOV lane be separated so that toll evaders cannot enter or exit the HOV lane at will. Separation is a key attribute that is effectively handled on priced HOV lanes that employ concrete barriers to separate opposing flow traffic. Continuous concrete barriers, such as permanently placed Jersey barriers or movable barrier systems, are permanent and durable and have been used for separation on a number of HOV facilities. They are also preferable from enforcement and traffic service perspectives as they prevent unauthorized vehicles from entering.

However, a majority of HOV lanes are likely to be concurrent flow designs. Separating these lanes may not be possible with concrete barriers. One design alternative applied in lieu of concrete barriers is plastic pylons or channelizers placed between concurrent managed lanes and general traffic in a designated and striped buffer area (Figure 3-49).
Tubular channelizers, pylons, or stanchions consist of a series of painted lightweight plastic tubes approximately three feet in height permanently affixed to the pavement at regular intervals. Because they rise vertically out of the pavement, they perform a greater psychological function than striping alone, but do not provide the physical protection of a continuous concrete barrier. One of their primary advantages is that they require a narrower buffer width than concrete barriers, which usually require separate breakdown shoulders along both roadways. Pylons on the State Route 91 project in California are positioned at 20-foot spacing and centered within a minimum 18-inch striped buffer. Maintenance issues are associated with all types of pylons. Experience shows that the displacement rate for traditional pylons is roughly 10 percent every 60 to 90 days, which means that all units would need to be replaced every year. Although generally durable, the adhesive-mounted plastic pylons can only be hit a certain number of times before they cease to bounce back up. They can also be hit with such force that they can dislodge from the pavement and become a hazard to traffic. Snow removal is also an issue as snow removal equipment can damage pylons, either by plowing snow onto the posts or by hitting them. Other types of vendor products are becoming available that may also be considered in providing a substantial separation between lanes.

Without physical separation, toll evasions cannot be effectively addressed. Some studies have suggested that lack of separation can be overcome by the frequent placement of tolling stations along the HOV lane (Figure 3-50).

### 3.7.2 Electronic Toll Collection

Electronic toll collection is the accepted means of applying pricing to HOV lanes and this practice will likely prevail on managed lanes. Each of the current demonstrations and many other tolled facilities across the country utilize electronic toll collection (ETC). ETC encompasses the use of various technologies for automated toll collection that eliminates the need for customers to stop and make cash transactions at a customary toll booth.
ETC systems rely on three major in-lane/roadway components:
- Automatic Vehicle Identification (AVI)
- Automatic Vehicle Classification
- Video Enforcement Systems

This equipment can be mounted on overhead gantries (Figure 3-52), or in the pavement to allow drivers to be charged while traveling at normal highway speeds. One AVI technology features a radio frequency device called a transponder, located in the vehicle that transmits a unique identity to an antenna located on a gantry or in a toll lane. This information is received by a toll reader located in an adjacent roadside cabinet. Sensors also located at the tolling point verify the vehicle classification typically based on the vehicle’s profile and number of axles, so that the proper toll can be charged. (The classification on the transponder is matched to the classification identity from the sensors. If there is a discrepancy between the two classifications the tolling administration agency sorts out payment or transactions for further investigations at a Violations Processing Center [VPC]). A video enforcement system can capture images of the license plates of toll evaders that use the facility. Those vehicle owners without a valid tag or with an observed discrepancy in classification can be identified as a violator. Legislation is typically enacted which allows the tolling administrator to pursue collection as a toll violation that includes the toll plus an administrative fee. All of these systems are linked by what is commonly referred to as a lane controller.

There is usually a single lane controller (micro processor) that coordinates the activities of all equipment monitoring the HOV lane, and it generates the transaction that is assigned to a particular customer. The lane controller also stores a list of valid tags so it can validate the information from the AVI. A larger computer collects transaction information from the lane controllers at each toll collection point and then communicates it to an administrative agency. The agency collects and consolidates information from one or more toll collection points in the system and transmits the list of valid tags to each lane controller for AVI validation, prepares audit report from each collection point, each lane and for each method of collection.
Some projects separate free HOV lane users from tolled users in the vicinity of the collection point (Figure 3-53). This design provides an opportunity for monitoring and inspection of free users from the toll traffic stream. Technology is also available which permits enforcement agents at any point along the lane, so segregation of HOV and toll traffic streams is not required. This design option is shown in Figure 3-51.

![Figure 3-51: Example Toll Gantry with Separate HOV Lane](image1)

![Figure 3-52: Example Toll Gantry Design without HOV Observation Lane](image2)

There are many observed variations on typical tolling systems described above. Putting this technology together can be a complicated process, and frequently administrative agencies hire a system integrator to add the technology to their existing toll environment or to develop a new toll system. Desirably, the selected transponder technology is compatible with other regional or statewide toll road operations so that user interoperability is possible with other facilities.

ETC implementation opportunities have largely been enabled by the changes in tolling technology. Automated or electronic means of collecting tolls through the use of various Automatic Vehicle Identification (AVI) systems has enabled tolling entities to collect toll fares without disruption to patrons or the roadway traffic flow. In addition to the
convenience of collecting the toll along the roadway, the overall cost of the collection activity is also significantly reduced.

While technology changes continue, the functional characteristics of the necessary tolling system remain the same. The tolling system involves an on-board device in the vehicle encoded with a unique ID used to identify the patron. The identification information is captured by roadside infrastructure (Figure 3-54), either at a tolling point or some other designated collection point, and passed through a communications network to a clearinghouse operation where the patron’s account is managed.

Figure 3-53: Example of Overhead RF Antennae Used with AVI (right) and Cameras Mounted at a Tolling Installation (left)

Key considerations in determining the applicability of any given technology include: operating functions, capital and operating costs (both agency and patron), security, product maturity, compatibility and interoperability with existing or planned systems, standards compliance, maintainability, and ease of use.

In all cases the tolling system design for managed lanes involve developing a fully automated electronic toll collection (ETC) system. These real-time systems include roadside or overhead radio frequency (RF) transmit/read devices communicating with on-board automatic vehicle identification (AVI) units in passing vehicles. The identification (ID) of the passing vehicle is combined with other transaction information collected in real-time, e.g. the current toll rate, then packaged and sent to host or central computer to be processed against the registered toll account. If an ID is not obtained, the system captures the event as a violation. These sophisticated systems enable the possibility of implementing HOT lanes by efficiently permitting the collection of a toll.

Although sophisticated, tolling applications use relatively straightforward technology. ETC involves linking an identification device in a vehicle to an account maintained by a host computer system through communications infrastructure. The technology and systems used today for traditional tolling applications are proven and mature.

There are several issues that influence the design of a managed lane tolling system. These issues are presented in detail below. The design priorities of any potential project
are also dependent upon the characteristics of the facility and the desired management strategy.

Long term options (10-20 year timeframes) may include the use of GPS combined with GIS mapping systems to assess road user fees. These fees may be determined by time-of-day or prevailing traffic conditions, by individual roadway or designated regions or areas, the possibilities are virtually endless since vehicle travel is recorded by time and location. Privacy concerns, in addition to challenges to integrate the technology into a fee collection system, will be the biggest hurdles for this technology.

If the integration of a GPS/GIS based solution has not been proven, the automotive industry will likely have fully embraced in vehicle telematics and will be supplying vehicles equipped with on-board DSRC identification, GPS technology, and other in-vehicle sensor systems, such as a seat occupancy systems, that will provide information to the on-board central unit that could be passed later to the roadside. Vehicle owners may be able to subscribe to any number of services, including a national toll account that can be used to travel on any tolled facility in the United States.

3.7.3 Technology

The benefits of capitalizing on an established ETC market of users, an established and stable revenue collection operation, and a program that is familiar to the public are enormous. Current RF based AVI systems are proven and mature and have been successfully integrated in ETC applications. Typically tolling systems involve proprietary software and complex hardware elements that require contracting directly with the manufacturer, supplier or system integrator. These services become more cost effective with scale, more naturally fitting the expansion of an existing system. The AVI function of ETC is defined within the industry as Dedicated Short Range Communications (DSRC). A DSRC standard is currently being developed that will standardize the technology applied for ETC and other Intelligent Transportation System (ITS) applications. Presently in the United States, all AVI equipment deployed in the field for ETC (transponders in vehicles and the roadside readers and antennas) operates in the frequency range of 902-928 MHz, a public frequency band. Several OEM’s have provided equipment and systems in this band and there is little inter-supplier compatibility among them and no protection from interfering RF sources. The evolving standard will require that all equipment operate in a dedicated and protected frequency band centered on 5.9 GHz and that all suppliers’ equipment be compatible. It is assumed that, at that time, the competition among the OEM’s will result in a competitive environment for the agencies and authorities, as well as enhancing the mobility of the driving public. While it will take some time until OEM’s qualify their products under the new standard, any new deployment planned should consider the ramifications of the implementation of the new standard. Its likely real changes won’t reach widespread field deployment before 2010, but they could become standard vehicle products after this time. RF based AVI deployments of ETC have changed very little over the last 10 years. The most substantial decision has always centered on using passive or active technology for the tag or transponder, often a choice between low cost, non-battery units or high cost, battery powered units. Typically there were also trade-offs between function and data.
storage. The majority of industry changes today involve designing lower cost, non-battery units which can also satisfy the more complex function and data storage requirements and never need replacing. These changes are also allowing the size of the units to decrease, which streamlines and improves distribution and supports point-of-sale purchasing from retailers of vending devices. Tag changes, designing multi-protocol readers and developing next generation DSRC products are the only technological changes being advanced for tolling.

All ETC tolling systems have the same general design parameters:

1. To identify the vehicle in the toll collection area by reading the identification number of the transponder (and other data that may be stored in the transponder) in the vehicle (the AVI function).
2. To determine the nature of the vehicle (known in the ETC field as classifying the vehicle) since most jurisdictions have different toll rates for different vehicle classes. This function is known as Automatic Vehicle Classification or AVC.
3. To photograph the license plate of the vehicle so that if any kind of violation occurs, the owner of the vehicle can be traced using the NDOT Department of Motor Vehicles files. Violations may include vehicles without a readable transponder, a vehicle class that does not correspond to class stored on the transponder, an invalid account held by the vehicle owner, among others.

To complete these functions, typically a well defined capture zone is established to detect and track the passing vehicle, communicate with the on board unit, interpret the on board data, and based on the interpretation determine the status of the event. A comprehensive planning and design phase should be completed and used to drive the technology solution.

3.7.4 Pricing Strategy

The selected pricing strategy affects the functional design of the ETC system for any managed lane facility. Managed lanes are designed to assess a road user fee that is inline with the value of reliable travel time to an SOV who is buying-in. In order to collect the road user fee some sort of tolling system is required. The design of the tolling system can be affected in two ways by the two major components of the pricing scheme to be implemented: 1) the price variability and 2) the price coverage area.

Price variability refers to the need to vary pricing according to a fixed, fixed variable, or dynamic variable toll rate schedule. Traditional toll facilities generally use fixed rate schedules according to vehicle classification. Some have introduced the concept of varying price by time of day, also known as fixed variable. For managed lane installations, pricing can also be set in real-time by the prevailing traffic conditions, an option known as dynamic variable pricing. Depending on the pricing concept to be used, the system design may involve additional subsystems, (e.g. traffic monitoring devices and advance signage, and / or more extensive modification to an existing toll collection operation, in order to accomplish the pricing mission).
Price coverage area relates to the roadway elements that are going to be priced. Is price being applied on a single facility, a corridor, or a region? The easiest to accommodate is a single or spot facility, which allows a toll to be collected at a particular trip point and is easily satisfied using traditional tolling techniques. Pricing will involve multiple tolling points to best regulate demand, and the rate structure may be defined by other parameters, e.g. miles traveled or specific route or roadway used. With traditional tolling techniques, multiple infrastructure locations are needed to determine what roadway or route is being used within the corridor and the various entry and exit locations. Regional pricing is similar to the corridor pricing model, multiple infrastructure locations are used to define the boundary of the priced region. Future tolling techniques might involve the use of Global Positioning Systems (GPS) that avoid the need for roadside infrastructure and potentially permit the application of dynamic, mileage-based fee across the entire roadway network.

Table 3-6 categorizes various tolling or pricing systems by the two major components of the pricing strategy. As suggested by the table, facility and corridor based toll systems employing variable pricing can be achieved with current ETC solutions. For applications looking to price regions or areas in any fashion, the table also clearly shows that solutions using existing ETC technology do not exist and alternative or future technologies may be better suited to address pricing needs.

<table>
<thead>
<tr>
<th>Pricing Area / Variability</th>
<th>Fixed</th>
<th>Fixed Variable</th>
<th>Dynamic Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot / Facility (including closed corridor facilities)</td>
<td>Traditional Toll Plazas</td>
<td>Some Toll Plazas, SR-91 HOT (CA), US 290 HOT (Houston)</td>
<td>I-15 HOT lanes (San Diego)</td>
</tr>
<tr>
<td>Corridor (multiple entry/exit and/or priced parallel routes)</td>
<td>Traditional Toll Plazas</td>
<td>IH-10 (Katy) HOT lanes (Houston)</td>
<td>I-394 HOT lanes Minneapolis</td>
</tr>
</tbody>
</table>

All users would be equipped with a transponder for identification and electronic toll collection (ETC). The pricing approach likely to be adopted would be dynamic pricing that is responsive to the level of service being experienced in the HOT lane. VIDs monitors would detect traffic flow rates and adjust pricing according to a prescribed plan that assures flow rates are sustained.

Managed lanes would be ETC equipped and potentially have a variable toll rate for each segment. Multiple toll zones could be anticipated with intermediate ingress/egress. Tolls should be able to vary by segment, with segments experiencing highest demand charged more than others. Some flat-fee based tolling might occur outside peak periods when benefits do not justify variable pricing to manage lane demand.

The project could take advantage of CMS signing if already applied for mainlane incident communication. Highway advisory radio and other means of communication could also
be employed to communicate toll information to motorists. Communication for toll transactions would go back to a remote office for processing via fiber connection.

3.8 Toll Operations Management

The operator of the toll system could be the NDOT, RTC or a third party contract or vendor. They would be serving the owner/client under prescribed policies regarding the minimum and maximum tolling thresholds, regulations regarding how the toll rate is changed, who is eligible for free or discounted use, and how the excess revenue is vested. They might also be charged with maintenance and operational reliability of the ETC infrastructure.

3.8.1 Preliminary ETC Cost Considerations

Operating costs likely to be incurred for a priced managed lane are divided into three categories: operations, maintenance and violation processing. Each category includes functional areas for the provision of services associated with the tolling operation. Operation costs involve administration, finance and accounting, customer service, and support staff at the tolling center. Operating expenses can include facility costs, office equipment costs, supplies and other direct costs associated with account management and revenue handling. In an established operation, the operating costs / expenses can be estimated to increase somewhere between $200,000 and $500,000 (2005 dollars) for every additional one million transactions processed. Maintenance costs involve preventative and corrective maintenance activities of the roadside tolling equipment and collection locations and central computer systems and application software. Maintenance expenses include facility and vehicle costs, technical support type contracts, and consumables. Depending on the scale of the deployment, maintenance service costs will vary widely depending on such factors as the number of tolling installations, access locations, operation and enforcement plan and length of the project.

Violation processing costs involve violation image review, finance and accounting, customer service, and appeals and hearing support. Additionally the cost of on-site enforcement activities and judicial or other adjudication proceedings must be included. Violation processing expenses include facility costs, office equipment, lookup fees, supplies and other direct costs associated with revenue handling. Excluding fixed costs for facilities and computer assets, the operating expenses in 2005 could be estimated to be between $100,000 and $500,000 annually per 100,000 violations processed, based on experiences from San Diego’s I-15 HOT lanes.

Operating costs can be significantly reduced if the operations activities are supported by web-based applications. On-line account management and payment, including for violation fines and fees, on-line account statements and other e-services dramatically reduce the cost of service center operations.

Table 3-7 provides some preliminary cost estimates for tolling infrastructure deployment that may be anticipated for a prototypical 6 to 8-mile simple managed lane operation with up to five tolling stations.
3.9 Systemwide Issues

Some of the systemwide design issues experienced in other areas involve the following, which should be considered in the design of any HOV or managed lane:

- **Consistency.** Design applications may have to address different operation regulations, but should look alike in signing and pavement markings.
  - *Suggestions:* Use the same geometric, signing and pavement marking criteria for successive projects. Test sign messages on a first project before repeating on successive projects.

- **Need for adequate lane balancing.** When two HOV or managed lanes come together, as often happens with a direct HOV access ramp between connecting facilities, downstream demand may exceed a single lane. These forced merge conditions between two HOV lanes that join from either separate routes or from a mainline and HOV flyover connector can cause queues that offset travel savings. These locations have created bottlenecks that have impacted both safety and operational performance of the respective system.
  - *Suggestions:* Carrying the commensurate number of lanes some distance downstream may be required in the design to effectively address demand. Otherwise, leave sufficient overall width to allow for restriping to two lanes at obvious future bottlenecks where demand may exceed a lane’s capacity. Design for future connections and direct access connectors.

- **Communication with Different Users:** Parallel roadways located in tight settings make placement of motorist information difficult. Over the years, many strategies have been tried to simplify messages through the use of carpool and bus symbols, or other strategies to address specific users. Inevitably the roadway sign guidance found in the MUTCD for optimal settings may not be completely applicable in concentrated urban settings with roadway and ramp designs that are below current design standards.
  - *Suggestions:* Local trade-offs will be needed to best accommodate information needs for the greatest number of users. Dynamic message signing (DMS) installations may help such situations, but only if the signing is allowed to address more than one user group, depending on the situation. For example, a DMS located over an HOV lane that normally provides occupancy or pricing information may have to serve a higher and better use by reporting a major accident ahead to all users. Diamond symbols should accompany signing intended for HOV or managed lane audiences, to direct the intended message to the correct audience. Most motorists understand that the use of the diamond on a sign is related to a restricted lane.
### Table 3-7: Preliminary Cost Estimates for ETC Pricing on a Managed Lane Facility

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit Price</th>
<th>Quantity</th>
<th>Extended Price</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Typical Pole Mount – Dedicated Directional Single Lane Median Divider (covers 2 lanes)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane Controller</td>
<td>$10,000</td>
<td>1</td>
<td>$10,000</td>
</tr>
<tr>
<td>ETC Reader</td>
<td>$10,000</td>
<td>1</td>
<td>$10,000</td>
</tr>
<tr>
<td>ETC Antenna</td>
<td>$2,500</td>
<td>2</td>
<td>$5,000</td>
</tr>
<tr>
<td>Enforcement Cameras</td>
<td>$5,000</td>
<td>2</td>
<td>$10,000</td>
</tr>
<tr>
<td>Pricing Signage (Type 1)</td>
<td>$10,000</td>
<td>2</td>
<td>$20,000</td>
</tr>
<tr>
<td>Pole Support</td>
<td>$10,000</td>
<td>1</td>
<td>$10,000</td>
</tr>
<tr>
<td>Communications Interface</td>
<td>$5,000</td>
<td>1</td>
<td>$5,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$70,000</strong></td>
</tr>
<tr>
<td><strong>Typical Cantilever – Dedicated Directional Single Lane (covers 1 lane)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane Controller</td>
<td>$10,000</td>
<td>1</td>
<td>$10,000</td>
</tr>
<tr>
<td>ETC Reader</td>
<td>$10,000</td>
<td>1</td>
<td>$10,000</td>
</tr>
<tr>
<td>ETC Antenna</td>
<td>$2,500</td>
<td>1</td>
<td>$2,500</td>
</tr>
<tr>
<td>Enforcement Cameras</td>
<td>$5,000</td>
<td>2</td>
<td>$10,000</td>
</tr>
<tr>
<td>Pricing Signage (Type 2)</td>
<td>$40,000</td>
<td>1</td>
<td>$25,000</td>
</tr>
<tr>
<td>Cantilever Support</td>
<td>$20,000</td>
<td>1</td>
<td>$10,000</td>
</tr>
<tr>
<td>Communications Interface</td>
<td>$5,000</td>
<td>1</td>
<td>$5,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$72,500</strong></td>
</tr>
<tr>
<td><strong>Typical Full Span Structure – Dedicated Directional Single Lane (covers 1 lane)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane Controller</td>
<td>$10,000</td>
<td>1</td>
<td>$10,000</td>
</tr>
<tr>
<td>ETC Reader</td>
<td>$10,000</td>
<td>1</td>
<td>$10,000</td>
</tr>
<tr>
<td>ETC Antenna</td>
<td>$2,500</td>
<td>1</td>
<td>$2,500</td>
</tr>
<tr>
<td>Enforcement Cameras</td>
<td>$5,000</td>
<td>2</td>
<td>$10,000</td>
</tr>
<tr>
<td>Pricing Signage (Type 3)</td>
<td>$75,000</td>
<td>1</td>
<td>$75,000</td>
</tr>
<tr>
<td>Full Span Support</td>
<td>$50,000</td>
<td>1</td>
<td>$50,000</td>
</tr>
<tr>
<td>Communications Interface</td>
<td>$5,000</td>
<td>1</td>
<td>$5,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$165,000</strong></td>
</tr>
</tbody>
</table>

Note: Generic cost estimates do not include any software modifications necessary to integrate sites into an existing system or for the cost of communications infrastructure to link the project to a remote site. No costs have been estimated for other instrumentation necessary to monitor traffic conditions or to provide video surveillance of the facility. No Automatic Vehicle Classification (AVC) equipment is included.

- **Flexibility.** A recent review of HOV projects implemented since 1969 showed that a high percentage had changed either their occupancy requirements, hours of operation, access or mainline design features over time. The reasons for such operation and design changes were many.
Suggestions: Designing in flexibility into the managed lane roadway system helps promote greater opportunity for future changes. Specific features that help promote flexibility include:

- Locating drainage inlets out of the shoulders or buffer areas
- Leaving wide clear zones around bridge columns
- Implementing changeable message signing where near term potential exists to add pricing or access features
- Casting and placing barriers that are not integral to the pavement, so that relocation can be more easily accommodated
- Placement of signs on common structures, even if the most optimal placement is compromised
- Using markings that can be easily altered in access zones until such time that operation confirms the length and location of the zone
- Providing shoulders on the mainline and ramps
- Maintaining proper clear zones around gores
- Avoiding superelevations and other physical separation between managed lanes and general purpose lanes
# Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AASHTO</td>
<td>American Association of State Highway and Transportation Officials</td>
<td></td>
</tr>
<tr>
<td>ASCE</td>
<td>American Society of Civil Engineers</td>
<td></td>
</tr>
<tr>
<td>AVO</td>
<td>Average Vehicle Occupancy</td>
<td></td>
</tr>
<tr>
<td>BRT</td>
<td>Bus Rapid Transit</td>
<td></td>
</tr>
<tr>
<td>CBD</td>
<td>Central Business District</td>
<td></td>
</tr>
<tr>
<td>CCTV</td>
<td>Closed Circuit Television</td>
<td></td>
</tr>
<tr>
<td>DMS</td>
<td>Dynamic Message Sign</td>
<td></td>
</tr>
<tr>
<td>EMS</td>
<td>Emergency Medical Services</td>
<td></td>
</tr>
<tr>
<td>ETC</td>
<td>Electronic Toll Collection</td>
<td></td>
</tr>
<tr>
<td>FAST</td>
<td>Freeway and Arterial System of Transportation</td>
<td></td>
</tr>
<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
<td></td>
</tr>
<tr>
<td>HCM</td>
<td>Highway Capacity Manual</td>
<td></td>
</tr>
<tr>
<td>HOT</td>
<td>High-Occupancy/Toll</td>
<td></td>
</tr>
<tr>
<td>HOV</td>
<td>High-Occupancy Vehicle</td>
<td></td>
</tr>
<tr>
<td>IDAS</td>
<td>ITS Deployment Analysis System</td>
<td></td>
</tr>
<tr>
<td>ILEV</td>
<td>Inherent Low Emission Vehicle</td>
<td></td>
</tr>
<tr>
<td>ITE</td>
<td>Institute of Transportation Engineers</td>
<td></td>
</tr>
<tr>
<td>ITS</td>
<td>Intelligent Transportation System</td>
<td></td>
</tr>
<tr>
<td>KSAs</td>
<td>Knowledge, Skills and Abilities</td>
<td></td>
</tr>
<tr>
<td>LED</td>
<td>Light Emitting Diode</td>
<td></td>
</tr>
<tr>
<td>LOS</td>
<td>Level-of-Service</td>
<td></td>
</tr>
<tr>
<td>MOE</td>
<td>Measure of Effectiveness</td>
<td></td>
</tr>
<tr>
<td>MOU</td>
<td>Memorandum of Understanding</td>
<td></td>
</tr>
<tr>
<td>MPH</td>
<td>Miles Per Hour (unit of speed)</td>
<td></td>
</tr>
<tr>
<td>MUTCD</td>
<td>Manual on Uniform Traffic Control Devices (latest edition)</td>
<td></td>
</tr>
<tr>
<td>NCHRP</td>
<td>National Cooperating Highway Research Program</td>
<td></td>
</tr>
<tr>
<td>NHI</td>
<td>National Highway Institute</td>
<td></td>
</tr>
<tr>
<td>NDOT</td>
<td>Nevada Department of Transportation</td>
<td></td>
</tr>
<tr>
<td>P&amp;P</td>
<td>Park-and-Pool</td>
<td></td>
</tr>
<tr>
<td>P&amp;R</td>
<td>Park-and-Ride</td>
<td></td>
</tr>
<tr>
<td>PPDM</td>
<td>Project Design Development Manual</td>
<td></td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
<td></td>
</tr>
<tr>
<td>ROW</td>
<td>Right-of-way</td>
<td></td>
</tr>
<tr>
<td>RTC</td>
<td>Regional Transportation Commission</td>
<td></td>
</tr>
<tr>
<td>SEC</td>
<td>Seconds (unit of time)</td>
<td></td>
</tr>
<tr>
<td>SOV</td>
<td>Single-Occupant Vehicle</td>
<td></td>
</tr>
<tr>
<td>STP</td>
<td>Surface Transportation Program</td>
<td></td>
</tr>
<tr>
<td>TCM</td>
<td>Transportation Control Measure</td>
<td></td>
</tr>
<tr>
<td>TCRP</td>
<td>Transit Cooperative Research Program</td>
<td></td>
</tr>
<tr>
<td>TDM</td>
<td>Transportation Demand Management</td>
<td></td>
</tr>
</tbody>
</table>
Terminology

The following terms have been borrowed from the Nevada Department Project Design Development Manual (2005 edition) and from various national guideline documents found in the Reference List. They represent the most current definitions for terms likely to be encountered in the development of ramp metering treatments and managed lane facilities.

**ACCESS** — The ability to enter or approach a facility or to make use of a facility. In the context of managed lanes, access generally refers to the location(s) where eligible vehicles are permitted to enter or exit the facility.

**ACCESSABILITY** — Measure of the ability or ease of individuals to travel among all origins and destinations in an area.

**ACCELERATION DISTANCE** — The distance needed for vehicles to accelerate to freeway speeds. For ramp metering this distance is usually measured from the ramp meter stop bar to the end of the ramp/freeway gore.

**ADD-A-LANE** — Term used to describe when an HOV facility is created by adding roadway capacity. The additional capacity may be accomplished by widening a freeway or arterial street, modifying a median or a shoulder, or by adding a new facility on a separate right-of-way.

**ADVANCE WARNING SIGN** — A sign posted on a ramp (upstream of a ramp meter) or along an adjacent arterial that gives advance warning to motorists of the presence of ramp meters on a ramp or the operational status of ramp meters.

**ARTERIAL STREET** — Provided for through traffic movement between areas and across the city, and direct access to abutting property; subject to necessary control of entrances, exits, and curb use.

**ARTICULATED BUS** — An extra-long, high-capacity bus. The rear portion of the vehicle is connected to the forward portion by an articulated section. Articulated buses have passenger seating for 60 to 80 persons, with additional space for standees. Vehicle length is from 60 to 70 feet. The turning radius for an articulated bus is usually less than that of a standard urban or intercity bus.

**AUXILIARY LANE** — The portion of the roadway adjoining the traveled way for parking, speed change, or other purposes supplementary to through traffic movements. In the context of freeways, auxiliary lane generally refers to a continuous lane (or lanes) resulting from the conjunction of a freeway entrance ramp with the adjacent downstream exit ramp.

**AVERAGE DAILY TRAFFIC** — The average 24-hour volume, being the total volume during a stated period divided by the number of days in that period. Unless otherwise stated, the period is a year. The term is commonly abbreviated as ADT.
AVERAGE OVERALL TRAVEL SPEED — For all traffic or component thereof, the summation of distances divided by the summation of overall travel time.

AVERAGE VEHICLE OCCUPANCY (AVO) — The total number of persons in all vehicles divided by the number of vehicles traveling past a selected point during a predetermined time period. AVO is usually expressed to two or three significant decimal places, such as 1.2 or 1.26.

AVERAGE VEHICLE RIDERSHIP (AVR) — The average number of employees who report to a work site divided by the average number of vehicles driven by these employees, calculated for an established time period. This calculation recognizes vehicle trip reductions from telecommuting, compressed work weeks, and non-motorized transportation.

BARRIER-SEPARATED — A HOV or managed lane or roadway that is physically separated from the adjoining general-purpose lanes by some type of physical barrier. A concrete barrier is the most commonly used approach, but wide buffers, movable concrete barriers, and plastic permanently-affixed pylons or channelizers may be considered a physical barrier. A barrier-separated lane may be a directional facility or a two or more lane two-way facility.

BUFFER — Designated pavement width separating an HOV or managed lane from adjacent general purpose lanes. The buffer width is typically four feet in width, but may be as narrow as two feet or as wide as 12 feet.

BUFFER-SEPARATED — An HOV or managed lane that is separated from the adjacent mixed-flow freeway lanes by a designated buffer.

BUS — A motor vehicle designed for the transportation of more than 10 persons.

BUS BAY — A designated area at a bus stop or transit station for buses to pull into to pick up and drop off passengers.

BUSPOOL — A form of bus service set up to serve one large employer or group of employers with limited origin and destination points. Buspools are often subsidized by the employer they serve, provide guaranteed seats for passengers, and have limited service.

BUS PRIORITY SYSTEMS — Techniques and strategies to improve the movement of buses in heavily traveled corridors, usually on arterial streets, which may include priority at traffic signals, phasing and coordinating traffic signals, and other treatments.

BUSWAY — A preferential roadway designed exclusively for use by buses. Busways are usually constructed in separate rights-of-way, but may be located within a freeway or roadway right-of-way.

BYPASS LANE — A separate HOV or managed lane that circumvents a traffic queue, typically a queue of entering vehicles at a ramp meter.

CAPACITY — The maximum number of vehicles which has a reasonable expectation of passing over a given section of a lane or a roadway an one direction (or in both directions for a 2-lane or 3-lane highway) during a given time period under prevailing roadway and traffic conditions.
CARPOOL OR CARPOOLS — Any automobile or private vehicle containing two or more occupants including the driver.

CARPOOL LANE — Another term used to describe an HOV lane, especially in areas with lower levels of bus service and high numbers of carpools.

COLLECTOR STREET — Providing for traffic movement between major arterials and local streets, and direct access to abutting property.

CHANGE OF MODE — The transfer from one type of transportation vehicle to another. For example, changing from driving alone to taking a bus at a park-and-ride lot represents a change of mode.

COMMUTE TRIPS — Trips that are made on a daily or regular basis to work, including those with intermediate stops to and from a work site.

COMMUTE ALTERNATIVES — Alternatives to driving alone such as carpools, vanpooling, transit, bicycling, and walking, or alternative work schedules that shift, commute trip to less congested periods, or remove work trips from the system altogether.

COMMUTE ASSISTANCE PROGRAMS — Programs which provide services to help commuters identify and use alternative modes, such as ridesharing and transit, and provide support facilities and services.

CONCURRENT-FLOW LANE — An HOV or managed lane that operates in the same direction as the adjacent general purpose lanes, and is designed for use by eligible vehicles during all or a portion of the day. The lane is usually separated from the adjacent general-purpose freeway lanes by a standard lane stripe or a buffer. Concurrent flow lanes are usually found on the inside lane, but may also be on the outside lane.

CONGESTION PRICING (a.k.a. VALUE PRICING) — The concept of charging a toll or fee for the use of a transportation facility, such as a roadway, based on the level of traffic congestion. The greater the level of congestion, which usually occurs during the morning and afternoon peak-periods, the higher the cost to use the facility.

CONTRAFLOW LANE — A HOV or managed lane operating in a direction opposite to the normal flow of traffic designated for peak direction travel during at least a portion of the day. Contraflow lanes are usually separated from the off-peak direction general-purpose lanes by plastic pylons or moveable barriers.

CORRIDOR — A strip of land between two termini within which traffic, topography, environment and other characteristics are evaluated for transportation purposes.

CRITERIA — Documentation used as the basis of a design.

CYCLE LENGTH — The total time for a signal to complete one cycle.

DEADHEAD — The trip a transit vehicle makes when not in revenue service to begin, end or transition between designated revenue service. Oftentimes, this term refers to the off-peak direction trip an express bus makes between successive revenue service runs.

DELAY — The time lost while traffic is impeded by some element over which the driver has no control.
DELINEATOR — A device (often light reflecting) mounted at the side of the roadway, in series with others, to indicate the alignment of the roadway.

DENSITY — The number of vehicles per mile on the traveled way at a given instant.

DESIGN ALTERNATIVE — One design from among those that are proposed for a particular transportation system improvement. A proposal to “do nothing” is a design alternative.

DESIGN CAPACITY — The maximum number of vehicles that can pass over a lane or a roadway during one hour without operating conditions falling below a pre-selected design level.

DESIGN HOURLY VOLUME — The traffic volumes on which the functional design of a highway is based. The design hourly volume normally represents the 30th maximum hourly volume 20 years from the anticipated year of construction. The term is commonly abbreviated as DHV.

DESIGN VEHICLE — A selected motor vehicle of which the weight, dimensions, and operating characteristics are used to establish highway design controls that will accommodate a range of vehicle types. Design vehicles are distinguished as either physical or operational depending on what features of the facility they apply to. The movements of a physical design vehicle are not prohibited by restrictive infrastructure such as signal poles, but traffic control measures such as striping and channeling islands may be contravened during some maneuvers. The movements of an operational design vehicle can occur within the limits established by the traffic control measures such as striping and channeling islands.

DESIRABLE — A condition or standard that is deemed to provide the best benefit for the associated cost under normal and reasonable circumstances. Desirable standards and conditions should be used or achieved.

DETECTORS — A device that detects a vehicle’s presence. The most common detectors are inductive loop detectors located in the pavement and overhead presence detectors located on traffic signal masts.

DIAMOND LANE — A term sometimes used to refer to an HOV lane due to the diamond symbol on signing and pavement markings.

DIAMOND SYMBOL — The diamond symbol is commonly used on signing and pavement markings to designate an HOV lane or other restricted lane.

DIAMOND INTERCHANGE — A 4-leg interchange with a single one-way ramp in each quadrant. All left turns are made directly on the minor highway.

DIRECTIONAL SPLIT — The distribution of traffic flows on a two-way facility, usually expressed as a percentage of the total two-way traffic.

DIRECT CONNECTION (or DIRECT CONNECTOR) — A directional ramp providing an unimpeded link between two intersecting roadways.

DIRECTIONAL INTERCHANGE — An interchange, generally having more than one highway grade separation, with direct connections for the major turning movements.
DOWNSTREAM — The direction in which traffic is moving.

DRIVER BEHAVIOR — The full range of human responses to the various stimuli that may be encountered while driving. Often reduced to the typical range of responses or classified by various driver traits such as age or ability.

DRIVER EXPECTANCY — The assumptions that form the reasonable driver’s anticipation for the impending sequence of events based on past driving experience and training.

DRIVER PERFORMANCE — The interaction of drivers with the highway and its information system.

EGRESS — The provision of access out of a HOV lane, managed lane, freeway, or roadway. Providing access into the lanes is ingress.

EMERGENCY VEHICLE — Any vehicle used to respond to an incident or accident. Examples include police cars, fire engines, ambulances, tow trucks, and maintenance vehicles.

ENFORCEMENT — The function of ensuring that the rules and regulations relating to the use of an HOV facility, such as vehicle occupancy levels, are abided by. The state police, transit police, or local police are usually responsible for enforcement activities.

ENFORCEMENT AREA — An area for enforcement vehicles and personnel to monitor the HOV lane and to stop vehicles to issue citations. Enforcement areas may be delineated within an available shoulder or provided at specific locations such as entrances and exits.

ENTRANCE RAMP — A ramp that allows traffic to enter a freeway.

EQUITY — A normative measure of fairness of a transportation project or a strategy among all users.

EXIT RAMP — A ramp for traffic to depart a freeway.

EXPRESS BUS SERVICE — Bus service with a limited number of stops, either originating and traveling non-stop from a specific location or serving a limited number of stops along a route to a destination.

FIXED DELAY — Delay caused by fixed time traffic controls.

FREEWAY — An expressway with full control of access.

FREEWAY-TO-FREEWAY RAMP METERING — The metering of ramps that connect one freeway to another.

FRONTAGE ROAD — A public street or road auxiliary to and normally located alongside and parallel to a freeway or expressway for purposes of maintaining local road continuity and for control of access. A frontage road is connected to public roads or streets at both ends, or at least one end of which is not the expressway to which it is appurtenant.

GENERAL-PURPOSE LANES (a.k.a mixed-flow lanes) — The travel lanes on a freeway or roadway that are open to all motor vehicles.
GORE — The area immediately beyond the divergence of two roadways, bounded by the edges of those roadways.

HEADWAY — The time interval between buses operating on a route or out of a transit facility.

HIGH-OCCUPANCY TOLL (HOT) LANE — Concept of using congestion or value pricing on a toll or HOV facility. An example would be charging variable toll rates depending on the number of people in a vehicle and the time of day.

HIGH-OCCUPANCY VEHICLE (HOV) — Motor vehicles with at least two or more persons, including carpools, vanpools, and buses. Individual HOV facilities may require different vehicle occupancy levels, which are usually expressed as either two or more (2+), three or more (3+), or four or more (4+) passengers per vehicle.

HIGH-OCCUPANCY VEHICLE (HOV) FACILITY — A lane(s) or roadway dedicated to the exclusive use of specific high-occupancy vehicles, including buses, carpools, vanpools or a combination thereof, for at least a portion of the day.

HIGH-OCCUPANCY VEHICLE LANE — A lane designated for exclusive use by high-occupancy vehicles (HOVs) for all or a portion of the day. An HOV lane may be on a freeway, roadway, arterial street, or in a separate right-of-way.

HIGH-OCCUPANCY VEHICLE (HOV) NETWORK — Planning, designing, implementing, and operating HOV lanes, park-and-ride facilities, transit services and facilities, and other elements, usually developed in an incremental, but coordinated, manner.

HIGH-OCCUPANCY VEHICLE (HOV) SYSTEM — The development and operation of a coordinated approach of physical improvements, such as HOV lanes and park-and-ride lots, and supporting services and policies.

HYBRID — Vehicle that uses both a conventional and alternative energy mode, usually battery, to provide more efficient operation. Hybrid vehicles are also defined in the 2005 federal transportation bill (SAFTEA-LU) as to their eligibility in HOV lanes.

INCIDENT MANAGEMENT — The development, oversight and implementation of procedures for efficiently and effectively minimizing the negative impacts that traffic incidents have on the flow of traffic.

INHERENT LOW EMISSION VEHICLE (ILEV) — A vehicle that is classified by federal guidelines as having a low enough emission rating to be considered eligible for using federally funded HOV lanes.

INTELLIGENT TRANSPORTATION SYSTEMS (ITS) — The application of a wide range of advanced technologies to enhance the operation and management of the surface transportation system.

INTERCHANGE — A system of interconnecting roadways in conjunction with one or more grade separations, providing for the movement of traffic between two or more roadways on different levels.
LANE CONVERSION – Term used to refer to the implementation of an HOV lane created by converting a general-purpuse lane on a freeway or arterial street. Used interchangeably with take-a-lane.

LEVEL OF SERVICE — A qualitative rating of the effectiveness of a highway in serving traffic, measured in terms of operating conditions. Note: The Highway Capacity Manual identifies operating conditions ranging from “A” for best operation (low volume, high speed) to “F” for poor operation at capacity conditions.

LINE-HAUL — That portion of a commute trip that is express or nonstop between two points. The term is usually used to define the express portion of a transit trip.

LOCAL STREET — A street or road primarily for access to residence, business, or other abutting property.

LONGITUDINAL TRAFFIC BARRIER — A generic term for highway features intended to prevent vehicles from traveling off the road into the adjacent roadside.

LOOP RAMP — A one-way turning roadway that curves about 270 degrees to the right to accommodate a left-turning movement. It may include provision for left turns at a terminal to accommodate another turning movement.

LOOP DETECTOR — A type of detector that is embedded in the pavement to serve the purpose of detecting the presence of vehicles.

MAJOR STREET — An arterial highway with intersections at grade and direct access to abutting property, and on which geometric design and traffic control measures are used to expedite the safe movement of through traffic.

MANAGED LANE — Highway facilities or designated lanes in which operational strategies are implemented and managed (in real time) in response to changing conditions.

MAXIMUM — The absolute allowable limit for a standard or condition where the quality of the design diminishes with increasing values of the standard. See minimum.

MEASURES OF EFFECTIVENESS (MOEs) — Criteria or measures that identify the threshold level of change or benefits anticipated from a transportation improvement or project. MOEs are used in evaluating the impact of an HOV facility or other project.

MERGING — The converging of separate streams of traffic into a single stream.

MERGING END — An end of an island, or area between converging roadways, beyond which traffic merges.

MINIMUM — The absolute allowable limit for a standard or condition where the quality of the design diminishes with decreasing values of the standard. See maximum.

MINIMUM TURNING RADIUS — The radius of the path of the outer front wheel of a vehicle making its sharpest turn.

MIXED-FLOW LANES (a.k.a. general-purpose lanes) — Travel lanes on a freeway or arterial street open to all traffic and vehicles.
MODE — A particular form of travel conveyances, including buses, automobiles, carpools, vanpools, single occupant vehicles, walking, bicycling, rail, air, and water-borne vessels.

MODE SHIFT — The act of changing from one mode, such as driving alone, to another mode, such as taking the bus.

MODE SPLIT — The proportion of total person-trips using the various modes of travel.

MOTOR VEHICLE CRASH — Any event that results in unintended injury or property damage attributable directly or indirectly to the motion of a motor vehicle or its load.

MOTOR VEHICLE TRAFFIC CRASH — Any motor vehicle crash occurring on any highway, street, road, or any way or place of which any part is open for the use of the public.

OFF-LINE STATION — A mode transfer facility located off of an HOV lane, or other fixed guideway system, either adjacent to the facility or a short distance away.

OFF-PEAK DIRECTION OF TRAVEL — The direction of travel in a corridor experiencing lower demand during a peak commuting period. In a radial corridor, the off-peak direction has traditionally been away from the central business district in the morning and toward the central business district in the evening. This situation is no longer the case in many metropolitan areas and in suburban areas, circumferential freeways often experience congestion in both directions.

OFF-PEAK PERIOD — The period of time outside the peak commuting period, usually the midday, evening, night, and early morning.

ON-LINE STATION — A mode transfer facility located along a HOV lane or a fixed guideway system.

ON-TIME PERFORMANCE — The measure, usually a percentage, of times that a transit vehicle meets the published schedule arrival time within a policy window.

OPERATING SPEED — The highest running speed that a reasonable driver can travel on a given roadway section under prevailing conditions and without exceeding the design speed.

OPERATIONAL DELAY — Delay caused by interference between components of traffic.

OUTER SEPARATION — The portion of an arterial highway between the traveled ways of a roadway for a through traffic and a frontage street or road.

OVERPASS — A grade separation structure where the subject highway passes over an intersecting highway or railroad, also called Over-crossing.

PARK-AND-POOL LOT — A facility where individuals can park their private vehicle and join a carpool or vanpool. The facility is not normally served by public transportation.

PARK-AND-RIDE LOT — A facility where individuals can park their private vehicle for the day and access public transportation or rideshare for the major portion of their
trip. Park-and-ride lots are found with HOV facilities, LRT, heavy rail, commuter rail systems, and ferry services.

**PASSENGER CAR** — A motor vehicle, except motorcycles, designed for carrying 10 passengers or less and used for the transportation of persons.

**PEAK DIRECTION AND PEAK DIRECTION OF TRAVEL** — The direction of higher travel demand during a peak commuting period. In a radial corridor, the peak direction has traditionally been toward the central business district in the morning and away from the central business district in the evening. This situation is no longer the case in many metropolitan areas and in suburban areas, circumferential freeways often experience congestion in both directions.

**PEAK HOUR** — The hour in the morning and in the afternoon when the maximum demand occurs on a given transportation facility or corridor.

**PEAK PERIOD** — The time period in the morning and in the afternoon when the heaviest demand occurs on a given transportation facility or corridor. Usually two or more hours.

**PERSON THROUGHPUT** — Term used to describe the number of persons, not vehicles, being carried on a facility. Usually measured at a specific point on the roadway facility for a predetermined period of time.

**PREFERENTIAL PARKING** — Parking lots, spaces, or other areas reserved for carpools and vanpools. Preferential parking is usually located closer to the destination, in a parking garage, or in some other area which is more desirable.

**PREFERENTIAL TREATMENT** — Providing special privileges to a specific mode or modes of transportation, such as bus lanes or signal priority for buses at intersections.

**PREVENTATIVE MAINTENANCE** — The systematic inspection, detection and correction of equipment that is in satisfactory working condition to prevent failures, either before they occur, or before they develop into major detects.

**PRIORITY LANE** — Lane providing preferential treatment to buses, carpools, and vanpools.

**PRIORITY LANE PRICING** — Concept of using congestion pricing or priority pricing on an HOV lane. Examples might include charging single-occupant vehicles for use of an HOV lane or charging 2+ carpools and allowing 3+ carpools to use the facility for free.

**PRIORITY PRICING** — Term used to describe the same concept as congestion pricing; that is charging for use of a transportation facility by time of day, level of congestion, or distance traveled, as well as providing lower rates for HOVs.

**PUBLIC TRANSIT AND PUBLIC TRANSPORTATION** — Passenger transportation service to the public on a regular basis using vehicles that transport more than one person for compensation, usually but not exclusively over a set route or routes from one fixed point to another. Routes or schedules of this service may be predetermined by the operator or may be determined through a cooperative arrangement.

**QUEUE** — A line of vehicles waiting to be served by a ramp meter.
RAMP — A short segment of roadway connecting two traffic facilities.

RAMP METER — A traffic signal that controls the entry of vehicles from a ramp onto a limited access roadway. The signal allows one or two vehicles to enter on each green or green flash.

RAMP TERMINAL — The area of a roadway which an entrance or an exit ramp joins with a surface street.

REGULATORY SIGNS — Signs that inform highway users of traffic laws or regulations, and indicate the applicability of legal requirements that would otherwise be apparent.

RESPONSIVE MAINTENANCE — Maintenance that is unplanned and is done when systems or equipment break down or require unexpected repair.

REVERSIBLE LANE — An HOV or managed lane in which the direction of traffic flow can be changed at different times of day to match the peak direction of travel during periods of peak demand.

ROAD, HIGHWAY OR STREET — A general term denoting a public way for purposes of transportation, including the entire area within the right-of-way. (Recommended usage: in urban areas use highway or street; in rural areas use highway or road.)

ROADWAY — The portion of a highway, including shoulders, designed for vehicular use. A divided highway is comprised of two, or more, roadways.

ROADWAY EXCAVATION — All excavation required in constructing the roadway prism including all roadway ditches that are a part of the roadway prism.

SERVICE VOLUME — The maximum number of vehicles that can pass over a given section of a lane or roadway in one direction on multi-lane highways (or in both directions of a 2 or 3 lane highway) during a specified time period while operating conditions are maintained corresponding to the selected or specified level of service. In the absence of a time modifier, service volume is an hourly volume.

SHOULD — Indicates an action that will be taken unless there is reasonable and justifiable cause not to. All reasoning and justification must be documented and, where required by policy, signatory approval must be included with such documentation. See shall and may.

SIGHT DISTANCE — The distance a person can see along an unobstructed line of sight.

SLIP RAMP — A diagonal ramp which connects a parallel frontage road to a freeway.

SPEED — The rate of vehicular movement, generally expressed in miles per hour.

SPEED CHANGE LANE — An auxiliary lane, including tapered areas, primarily for the acceleration or deceleration of vehicles entering or leaving the through traffic lane.

STATION — A major facility servicing one or more transit mode.

STREET, HIGHWAY OR ROAD — A general term denoting a public way for purposes of public transportation, including the entire area within the right-of-way. (Recommended usage: in urban areas use highway or street; in rural areas use highway or road.)
SUPPORT FACILITY — A physical improvement that enhances HOV operations, including park-and-ride lots, park-and-pool lots, transit centers and elements.

SUPPORT PROGRAM — Policies, programs, and services that enhance the public acceptance or usage of an HOV facility, including ridesharing programs, employer-sponsored incentives, public information, and marketing activities.

THROUGH HIGHWAY, ROAD OR STREET — Any highway or portion thereof on which vehicular traffic is given preference such that at intersections controlled by stop signs or a yield signs traffic from the intersecting highways are required to yield to vehicles on the through highway.

T INTERSECTION — A three-leg intersection in the general form of the letter “T”.

TOLL ROAD OR TOLL LANE — A highway or traffic lane open to traffic only upon payment of a direct toll or fee.

TRAFFIC CONTROL DEVICE — A sign, signal, marking or other device placed on or adjacent to a street or highway by authority of a public body or official having jurisdiction to regulate, warn, or guide traffic.

TRAFFIC INCIDENT — Any occurrence on a transportation facility that adversely affects the intended normal operation of the facility such as vehicle crashes, disabled vehicles, equipment malfunctions, special events, inclement weather, emergencies, etc.

TRAFFIC MARKINGS — All lines, patterns, words, colors, or other devices, except signs, set into the surface of, applied upon, or attached to the pavement or curbing or to objects within or adjacent to the roadway, officially placed for the purpose of regulating, warning, or guiding traffic.

TRAFFIC RESPONSIVE — A traffic signal timing approach which can be implemented in response to the direction of traffic flow.

TRAFFIC SIGN — A device mounted on a fixed or portable support whereby a specific message is conveyed by means of words or symbols, officially erected for the purpose of regulating, warning, or guiding traffic.

TRANSFER — The act of changing from one vehicle or route to another. Also, the paper provided to a passenger by a transit operator upon paying a fare that allows the individual to board the second vehicle without paying another fare.

TRANSIT — General term referring to all vehicles and systems that move more than one individual, includes carpools, vanpools, minibuses, buses, coaches, LRT, heavy rail, and commuter rail.

TRANSIT CENTER OR TRANSIT STATION — A facility serving transit buses and other modes such as automobiles and pedestrians. Centers and stations provide locations for individuals to access transit services and to transfer between buses or between buses and other modes.

TRANSITWAY — Term used to describe an HOV lane or facility. In some cases, it refers to bus-only facilities, but in other cases, it may be used on a facility open to all HOVs.
TRANSPORTATION CONTROL MEASURE (TCM) — A series of vehicle trip reduction measures focusing on reducing travel by single-occupant vehicles and increasing the use of buses, carpools, vanpools, and other alternative commute modes.

TRANSPORTATION PLAN — A program of action to provide effectively for present and future demands for movement of people and goods. This program must necessarily include consideration of the various modes of travel.

TRAVEL TIME — The average time spent by vehicles traversing a highway segment, including control delay, in seconds per vehicle or minutes per vehicle.

TRAVEL TIME RELIABILITY — Term referring to the lack of variability in travel time that can be expected using different facilities.

TRAVEL TIME SAVINGS — The time saved by use of an HOV facility rather than driving alone. Calculated by the difference in travel times between two points using the HOV facility and the general-purpose lane.

TRAVEL WAY — The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

TRUCK TRACTOR — A motor vehicle designed for drawing other vehicles but not for a load other than a part of the weight of the vehicle and load drawn.

TURNING MOVEMENT — The traffic making a designated turn at an intersection.

TURNING PATH — The path of a designated point on a vehicle making a specified turn.

TURNING ROADWAY — A connecting roadway for traffic turning between two intersection legs.

TURNING ROADWAY TERMINAL — The general area where a turning roadway connects with a through traffic roadway. “Exit” used as a modifier refers to leaving the through traffic lanes and “entrance” refers to entering the through traffic lanes.

TWO-WAY RAMP — A ramp for travel in two directions. At a cloverleaf it serves as both an outer connection and a loop.

UNDERPASS — A grade separation where the subject highway passes under an intersecting highway or railroad; also called Under-crossing.

UPSTREAM — The opposite direction to which traffic is moving.

URBAN INTERCHANGE — A Single Point Urban Interchange.

VANPOOL — A vehicle designed for the transport of typically between 6 and 15 passengers, operating on a pre-arranged schedule determined by the participants. Also defined as a pre-arranged ridesharing function in which a number of people travel together in a van designed to carry between 6 and 15 passengers.

VEHICLE — Any motorcycle, car, truck, van, bus, or rail car designed to carry passengers or goods.

VEHICLE OCCUPANCY — The number of people in a car, truck, bus, or other vehicle.

VIOLATION OF MANAGED LANE REQUIREMENTS — An infraction of the rules and regulations for use of an HOV facility or other transportation system. On an HOV or
managed lane facility, not having the required number of people in a vehicle or crossing over a restricted buffer are violations.

**VIOLATION RATE** — The number of vehicles that do not meet the minimum vehicle-occupancy level required to use an HOV or managed lane facility. Usually expressed as a percentage of the total vehicles using the lane during a predetermined time period.

**VOLUME** — The number of vehicles passing a given point during a specified period of time.

**WEAVING** — The crossing of traffic streams moving in the same general direction accomplished by merging and diverging.

**WEAVING SECTION** — A length of one-way roadway designed to accommodate weaving at one end of which two one-way roadways merge and at the other end of which they separate.

**References and Additional Glossaries**


Appendix B
Federal-Aid Highway Program Guidance on High Occupancy Vehicle (HOV) Lanes

This guidance is presented in 3 general sections. The first part provides background information and the Federal policy position regarding HOV lanes, and identifies when a Federal review is needed if a significant change in the operation of HOV lanes is contemplated. The next section describes the Federal review and the applicable requirements and regulations. The last two sections contain a list of the definitions and references used in this guidance. A summary of the regulatory requirements related to HOV lanes for the Federal-aid programs administered by the Federal Highway Administration (FHWA) is provided as Attachment 1.

Purpose:

In accepting Federal-aid funds, agencies have agreed to manage, operate, and maintain HOV lanes as they were originally planned, designed, constructed, and approved. However, conditions change over time, and this guidance includes provisions to address these situations. The purpose of this guidance is to identify when a detailed review of a proposal to significantly change the operation of existing HOV lanes is needed, and the Federal actions that may be required.

Changes to the minimum number of people to be in a vehicle in order to use HOV lanes (for example, from 3 occupants to 2), or small adjustments to when HOV restrictions begin or end, are typically not considered significant operational changes and are not normally causes for further Federal review. However, a proposal to significantly adjust the hours of operation or to convert an HOV lane to a general purpose lane, is considered a significant operational change. Changes that do not comply with the original project design concept, or scope, require a further Federal review. Federal interests for seeking this review include consistency with the provisions of Title 23 and Title 49 of the United States Code (23 U.S.C. and 49 U.S.C.), operational commitments made during the National Environmental Policy Act (NEPA) process as described in Title 23 Code of Federal Regulation, Part 771 (23 C.F.R. Part 771), in project agreements, transportation planning requirements, and transportation conformity requirements under the Clean Air Act (40 C.F.R. Parts 51 and 93).

The questions and answers on the following pages provide more detail about:

- what is to be included in the initial proposal from an operating agency wishing to change the operation of its HOV lanes;

- what circumstances require a more detailed review for Federal actions; and

- what should be reviewed relative to the various Federal requirements.

Section 1: Federal Policy Position and Need for Federal Review

What is FHWA's policy position on high occupancy vehicle (HOV) lanes?

FHWA strongly supports HOV lanes as a cost-effective and environmentally friendly option to help move people along congested urban and suburban routes. As part of an overall approach to handle the demand for travel and to address the impacts of traffic congestion, HOV lanes can be a practical option to adding more general purpose travel lanes. The FHWA encourages the implementation of HOV lanes as an important part of an areawide approach to help metropolitan areas address the needs they have identified for mobility,
Why and when is it appropriate to consider HOV lanes?

The primary purpose of an HOV lane is to increase the total number of people moved through a congested corridor by offering two kinds of travel incentives: a substantial savings in travel time, along with a reliable and predictable travel time. Because HOV lanes carry vehicles with a higher number of occupants, they move significantly more people during congested periods, even if the number of vehicles that use the HOV lane is lower than on the adjoining general purpose lanes. In general, carpoolers, vanpoolers, and bus patrons are the primary beneficiaries of HOV lanes by allowing them to move through congestion. However, if there isn’t significant roadway congestion during the peak periods, along with a significant job base beyond the HOV lanes, it will be difficult to attract riders. Experience with HOV lanes from around the country has shown a positive relationship between ridership and travel time savings, suggesting as congestion grows, the travelers willingness to carpool or ride on a bus that uses an HOV lane, also grows. (1, 2, 3)

What are the benefits of HOV lanes? When during the day are HOV lanes appropriate?

In Texas, experience has shown that HOV lanes carry up to 40 percent of the total people in a corridor during the peak hour and save on average from 2 to 18 minutes of travel time in the morning rush hour. HOV lanes in Texas have a benefit to cost ratio ranging from 6:1 to 48:1, and in each case, demonstrating a cost-effectiveness that is greater than if two additional general purpose lanes had been added. (1)

During off-peak periods, the Washington DOT found that the HOV lanes are well used when congestion exists, which increasingly extends beyond the traditional peak travel periods. The average number of people in each car is higher than what was expected during non-peak periods, especially on weekends. A study performed in the Seattle area on weekend freeway use found that 30-60 percent of weekend traffic is HOV eligible, and when congestion occurs, these vehicles use the HOV lanes. (3)

What changes can be made to improve the operation of HOV lanes?

Driver frustration with HOV lanes perceived to be operating inefficiently, can over time result in a negative public sentiment against HOV lanes, which may potentially influence proposals to make significant operational changes to, or convert the HOV lane to a general purpose lane. Agencies are encouraged to pro-actively manage and operate, each HOV lane in a region, to continually improve their performance. Examples of possible operational strategies to improve the performance of an HOV lane may include:

-- Provide park-and-ride facilities and direct access or connections to HOV lanes;
-- Enhance the transit service along the corridor;
-- Changing the occupancy requirement or hours of operation to use an HOV lane; and
-- Allowing lower occupant vehicles to use HOV lanes by charging a fee (HOT lane).

Proven travel demand management (TDM) strategies that have been used to improve HOV system performance on both a region wide and facility specific basis include: ride sharing and guaranteed ride home programs; telecommuting and alternate work schedules; growth management, land use policies, and zoning ordinances; pricing (e.g., HOT lanes); parking management; trip reduction ordinances; park-and-ride lots; and traveler information systems.
Are HOV lanes always a good idea?

HOV lanes are not appropriate in every location or for every situation. Even after they are installed, changes occur in land use, the kinds of trips people take, the times people travel, and the levels of traffic congestion, which may warrant adjustments in the operation of the HOV lanes.

Does an agency have to get Federal approval to change how it operates its HOV lanes?

In general, no. Agencies that own and operate the HOV lanes have the authority and the responsibility to decide how they are operated. But, as described in more detail later, there are situations when proposals to significantly change the operation of HOV lanes (e.g., the conversion of HOV lanes to general purpose lanes) will require some Federal review and may require potential action.

What are FHWA's interests and role related to the operation of HOV lanes?

Agencies that own and operate HOV lanes are encouraged to involve the FHWA Division Office in the development of programs and initiatives to monitor how well the lanes are functioning, to assess their effectiveness with improving the efficiency of travel, to identify new strategies to improve performance, or to analyze the impacts of any significant changes to either the transportation system (including how it is operated), regional HOV system, or both.

Converting HOV lanes to general purpose lanes is always considered a significant operational change to the original project's design concept or scope. In addition, a significant operational change may involve any action that has the potential to adversely affect the area's flow of traffic, roadway and traveler safety, and the environment. To assure consistency with the Federal-aid program provisions of 23 U.S.C. and 49 U.S.C., a review of the important issues and possible impacts of any significant operational changes is needed, to determine if any Federal approval is required.

Note that the type of program funds originally used to design or construct the HOV lane is of particular federal interest. Certain Federal-aid program funds have specific limitations on their use and such uses cannot be changed unless specifically authorized by Federal statute. FHWA Division Offices, with involvement as appropriate from the Federal Transit Administration (FTA), are responsible for reviewing proposals to significantly change the operation of HOV lanes. Additional detail on significant operational changes to an HOV lane is provided in Section 2 of this guidance.

When would Federal actions be needed related to the operation of HOV lanes?

FHWA must be consulted if a proposed significant operational change can be reasonably expected to affect a specific HOV lane or portions of the regional HOV system, which were funded or approved by FHWA. This includes portions of the local, region, or Federal-aid Highway system, where operational changes to these facilities may also adversely affect the operation of one HOV lane, or portions of the regional HOV system. Applicable federal interests include consistency with the provisions of 23 and 49 U.S.C., approved projects and applicable mitigation commitments made pursuant to the NEPA process as described in 23 C.F.R. Part 771, in project agreements, transportation planning requirements, and transportation conformity requirements under the Clean Air Act (40 C.F.R. Parts 51 and 93).

Agencies should provide the FHWA Division Office with a brief proposal describing the proposed change to the operation of their HOV lanes. This proposal should describe:

-- the specific proposed change in operation and the reason for it;
-- the affected roadway and the geographic extent of the proposed change;
-- the category or source of any Federal funding that has been used for implementing the HOV lanes (including those changed or affected by the change); and

-- any discussions with other affected agencies (e.g., planning organizations and neighboring operating agencies).

**What are the specific circumstances that require Federal review and possible action?**

On a case-by-case basis, a review of proposals to change the original design concept, scope, or operation of the HOV lanes will determine if a Federal approval is required, or if any other actions may be necessary before the proposed changes occur. Federal approval is required if:

-- the proposed HOV lane conversion is located in an air quality non-attainment or maintenance area;

-- a significant change in the operation of an HOV lane could affect the transportation plan and transportation improvement program (TIP) conformity determination;

-- the HOV lanes were included in the approved State Implementation Plan (SIP) as a transportation control measure (TCM);

-- there are potential new or greater environmental impacts than were originally analyzed pursuant to the NEPA process, or conflicts with mitigation commitments contained in project decision documents; or

-- particular categories of Federal-aid funding were used to acquire right-of-way, design, or construct the HOV lanes.

The details and expected impacts resulting from the proposed operational change or agency action must be analyzed and submitted to the appropriate FHWA Division Office to initiate this review.

**What is the purpose of the Federal review?**

The review will determine if other Federal actions or approvals are needed, as well as what those actions are, and when they should happen. This review will assess:

1. the original approvals granted and commitments made that assumed the HOV lanes would remain in place;
2. the impacts of the proposed change on operational and safety issues;
3. environmental impacts of the proposed change and whether compliance with NEPA is required; and
4. consistency with existing transportation conformity determinations.

**What information should be part of a Federal review?**

The following information, along with any additional data or analysis that an agency believes justifies a significant change in HOV lane operation or conversion, will serve as the basis for the FHWA review:

1. Original HOV lane studies, plans, project agreements, legislative history, sources and amounts of funding;
2. Commitments made in the environmental processing and project approval;
3. Operational assessment of existing HOV lanes (i.e., traffic characteristics, HOV usage, people transported, etc.); description of support programs and services (i.e., park-and-ride lots, carpool and vanpool initiatives, marketing, etc.); description of roadway construction or other activities that may have affected HOV lane or system performance; trends in HOV operational
characteristics over time; and other agency initiatives implemented to improve the efficiency of the HOV lanes;

4. Analysis of predicted operation of the current and planned future transportation network with the proposed operational change or conversion (i.e., affect of the proposal on the existing and future improvements planned for the facility, corridor, HOV and regional surface transportation systems; air quality conformity; potential environmental effects of the proposed conversion or operation; other environmental impacts; regional transportation plans (e.g., congestion management system, regional HOV system plan, region or statewide transportation plan); safety features; and design standards);

5. An assessment of the predicted performance of alternate lane management strategies in place of, or in addition to, the existing HOV lane, such as pricing (e.g., HOT lane, toll lane), express, transit; or truck lanes;

6. Identification as a non-attainment or maintenance area, if applicable. If the HOV lane is located in such areas, provide the date of the latest conformity determination for the transportation plan and the TIP; and

7. Was the HOV lane included in the approved SIP as a TCM and is a modification of the SIP required.

Based on the results of this review, FHWA and FTA will determine if the proposed action complies with these requirements. If it is determined that the proposed action complies with these requirements, no further federal action will be required.

If the proposed action to significantly change the operation of the HOV lanes is determined not to comply with these requirements, then the change will not be approved. If an agency implements a change which has been determined to be noncompliant with existing legislation or regulatory requirements, sanctions will be imposed by FHWA, consistent with 23 C.F.R. 1.36, including withholding further federal highway project approvals. Section 2 contains additional details on the regulatory requirements, eligibility issues, and limitations related to HOV lanes with the Federal-aid programs that are administered by FHWA.

Are there recommended procedures to evaluate the performance of an HOV lane?

Agencies are encouraged to develop and support initiatives that continuously monitor and evaluate how well the HOV system, specific lanes, or support programs are performing. The results of the performance evaluation provide the basis for making revisions to improve the operation of the HOV system or specific lanes. Technical guidance and recommended practices on performance monitoring and evaluation of HOV systems can be found in the FTA report titled "Suggested Procedures for Evaluating the Effectiveness of Freeway HOV Facilities" or the National Cooperative Highway Research Program Report 414: "HOV Systems Manual."

These reports identify a recommended framework and components of a continuous performance monitoring and evaluation activity, along with suggested procedures for analyzing the operation of a specific HOV lane or support programs. The purpose of monitoring and evaluating the performance of an HOV lane or support program, is to assess the influence or impacts that have accrued, and to determine if they are meeting their identified goals and objectives. The deficiencies identified from these evaluations should serve as a direct input into immediate decisions that are made to improve the operational efficiency and safety of the HOV lane.
Section 2: Federal Requirements

The following section highlights the requirements that should be considered in reviewing agency proposals to significantly change the operation or convert HOV lanes into general purpose travel lanes.

What are the requirements for the minimum number of people to be an HOV?

23 U.S.C. 102(a)(1) says that "State highway department shall establish the occupancy requirements of vehicles operating in high occupancy vehicle lanes; except that no fewer than 2 occupants per vehicle may be required."

Are any exceptions to the 2 persons per vehicle minimum allowed?

23 U.S.C. 102(a)(1) notes that "motorcycles and bicycles shall not be considered single occupant vehicles." Also, 23 U.S.C. 102(a)(2) notes that "...a State may permit a vehicle with fewer than 2 occupants to operate in high occupancy vehicle lanes if the vehicle is properly labeled and certified as an Inherently Low-Emission Vehicle." And Section 1216(a)(5) of the Transportation Equity Act for the 21st Century (TEA-21) notes that "...a State may permit vehicles with fewer than 2 occupants to operate in high occupancy vehicle lanes if the vehicles are part of a value pricing pilot program." In addition the Environmental Protection Agency (EPA) regulations in 40 C.F.R. section 88.313-93 allows Inherently Low Emission Vehicles (ILEV) of fleet owners to use HOV lanes.

What is an ILEV? What Regulations Exist?

ILEVs are a subcategory of clean-fuel vehicles that have essentially no fuel vapor emissions. These vehicles will have a single dedicated gaseous fuel (Compressed natural gas, liquid natural gas, or liquefied petroleum gas) systems. Vehicles that can operate on more than one fuel and/or an alcohol fuel cannot be classified as an ILEV vehicle. In addition, none of the hybrid-electric vehicles that have been certified by EPA, qualify as an ILEV because their engines use conventional gasoline.

Clean-fuel vehicles are certified by EPA to one of the following categories: Low-Emission Vehicles (LEVs); Ultra Low-Emission Vehicles (ULEVs); or Zero-Emission Vehicles (ZEVs). An ILEV is an exhaust emission classification that exists between the LEV and ULEV standards. EPA established the ILEV category of vehicles to encourage their use and recognize that there are certain technologies and clean fuels which have inherently lower emissions in the primary ozone precursors (hydro-carbons and oxides of nitrogen) than typical clean-fuel vehicles. Because the ILEV concept is a federal program, the program requirements, certification, labeling process, and other regulatory provisions are administered through EPA.

Since ZEVs are non-hybrid electric powered vehicles with no emissions, all certified ZEVs can be considered as ZEV-ILEVs. EPA certifies ZEV as both ZEV's and ILEVs when requested by the manufacturer. As such, our interpretation of the intent of section 1209 of TEA-21 is that in addition to ILEVs, vehicles certified by EPA as ZEVs could be exempted from HOV lane restrictions, if a State so chooses. The emissions standards corresponding to these categories of vehicles may be found in 40 C.F.R. Part 88.104.94(g). EPA maintains an updated list of vehicles certified as ILEVs or ZEV-ILEVs which can be found at the following web site: http://www.epa.gov/autoemissions

EPA is the only entity with the authority to certify ILEVs. There are a number of vehicles that have been converted in the field by entities known as aftermarket conversion companies. At this time none of these aftermarket conversions comply with EPA’s certification requirements, and therefore, cannot operate in an HOV lane. The first year that EPA certified any ILEVs was 1996.
ILEVs are exempt from meeting the normal HOV lane occupancy or vehicle type restrictions. However, this exemption for ILEVs does not include bus-only HOV lanes. The use of HOV lanes by ILEVs is not intended to cause congestion.

Therefore, use of HOV lanes by non-fleet ILEVs could be revoked, should the State determine it is necessary. Use of HOV lanes by fleet ILEVs could be revoked following a petition to EPA by the state in accordance with 40 C.F.R. section 88.313-93(c)(2). Section 241 of the Clean Air Act defines a fleet as ten or more vehicles that are owned or operated by a single person, meet the Clean Fuel Fleet Vehicle Program emission standards, and are capable of being centrally fueled.

Section 1209 of TEA-21 stipulates that labeling of ILEVs must be in accordance with section 40 C.F.R. section 88.312-93(c). These regulations require three labels, one to be attached to the rear of the vehicle and one to each side (the smallest is 10-inches by 7-inches). Manufacturers' and dealers are currently responsible for providing and applying labels to eligible vehicles when requested by customers.

EPA's regulations do not specify who will insure that the labels are properly attached to ILEVs. These regulations were written to apply specifically to vehicles operated by fleets in non-attainment areas that adopted the Clean Fuel Fleet program in the SIP. Due to the physical size of the labels, they may not be visually desirable to vehicle owners, or compatible with some of the smaller vehicles that have been certified as ILEVs by EPA. Therefore, vehicles certified as ILEVs may use a State approved label or license, and are not required to display the three labels that EPA requires for fleet operated vehicles.

Any State administered labeling program would need to certify that any allowable zero emission vehicle would conform to the EPA established ILEV standards. Prior to making a decision on whether to allow ILEVs or any zero emission vehicles to use HOV facilities, a thorough consideration of the issues related to the impact on travel demand, facility operations, enforcement, program administration, marketing, and continuous public outreach is recommended.

Why is the Federal government interested in how a locality operates its HOV lanes after they have been built?

In accepting Federal funds to acquire right-of-way, to design or construct HOV lanes, agencies agree to manage, operate and maintain the HOV lanes in a safe and efficient manner. The transportation system, particularly in urban areas, is a complex collection of interdependent modes, systems, infrastructure, facilities, and operational strategies. As a result, changes made to the operation of one mode or facility, can adversely affect the performance of other portions of the system. Our customers, the traveling public, expect a transportation system that meets their needs for mobility today, and into the future, in an effective and efficient manner, regardless of the mode or route.

When and for how long should there be requirements for a minimum number of occupants for a vehicle to use the HOV lanes?

An operational analysis of current and estimated future travel should be the basis for determining when, during a typical day, there should be an occupancy requirement for vehicles to use an HOV lane. HOV lanes may be operated on a 24-hour basis, for extended periods of the day, during peak travel periods only, during special events, or other activities. The requirement for a minimum number of occupants in a vehicle to use an HOV lane must be in effect for most and/or all of at least one of the usual times during the day when the demand to travel is greatest (e.g., the morning or afternoon rush hours). At a minimum, the vehicle occupancy requirements for an HOV lane must be in effect during the times of the day when the problems from traffic congestion on the roadways and within the transportation corridor are at their worst. These critical times may be identified when an area's Transportation Plan is developed and updated.

What would be considered a "significant" change to the operation of an HOV lane?
A significant operational change may involve any action that has the potential to adversely affect the area's flow of traffic, roadway and traveler safety, and the environment. A proposal to significantly adjust the hours of operation, or to convert an HOV lane to a general purpose travel lane, is considered a significant operational change. Changes which are considered inconsistent with the original project design concept or scope, would also require a Federal review as described in this guidance. Examples of significant operational changes could include:

-- switching from 24 hour HOV lane operation to only a portion of the day or week;

-- implementing a pricing option (e.g., HOT lane, toll lane) that would result in single occupant vehicles using an existing HOV lane;

-- any significant reduction in the hours of operation of the HOV lane, if it is operational only during one peak travel period; or

-- if an HOV lane is being managed and operated in a manner that renders it functionally inoperable or obsolete (e.g., if no enforcement of the occupancy requirement is provided).

Proposals to adjust only the HOV lane hours of operation during the day or the occupancy requirement, are typically not considered significant operational changes, and may not require an explicit Federal review or approval. However, even minor adjustments or changes to the highway system, specific HOV lanes, or portions of the regional HOV system, may be considered a significant operational change based on the effect it may cause. Examples of operational changes that are typically not considered significant changes could include:

-- making minor changes in hours during peak travel periods;

-- switching the occupancy level from HOV-3 to HOV-2; or

-- adding a pricing option to allow two occupant vehicles to use an HOV-3 lane.

If a test or demonstration project is proposed that seeks to significantly change the operation of the HOV lane for any period of time, it will require a review as described in this guidance, prior to initiating such a test or demonstration.

What should be reviewed related to an area's Congestion Management System (CMS)?

According to the transportation planning requirements noted in 23 C.F.R. 450.320(c), in Transportation Management Areas (TMAs), the planning process must include the development of a CMS that provides for the effective management of new and existing transportation facilities through the use of travel demand reduction, travel management, traffic operational strategies, and meets the requirements of 23 C.F.R. part 500. 23 C.F.R. 500.109 defines an effective CMS as a systematic process for managing congestion that provides information on transportation system performance, and on alternative strategies for alleviating congestion, to enhance the mobility of persons and goods to levels that meet State and local needs.

The CMS encourages the consideration and implementation of strategies that provide the most efficient and effective use of existing and future transportation facilities. Consideration needs to be given to strategies that reduce SOV travel and improve existing transportation system efficiency. A requirement of the CMS is to include implementation of a process for periodic assessment of the efficiency and effectiveness of implemented strategies, in terms of the area's established performance measures. The results from this evaluation may provide guidance as to the effectiveness of different strategies, or revisions to the management and operation of an existing strategy, to improve the facility’s performance.

Therefore, if the HOV system or a particular lane is found to not meet the established performance thresholds, agencies are encouraged to make revisions to improve their operation. However, where the
conversion of an HOV lane to a general purpose lane is determined to be the appropriate operational change, then explicit consideration is to be given to the incorporation of appropriate travel management and traffic operational strategies to accommodate future travel demand and maintain the functional integrity of the facility. These travel management and traffic operational strategies may include but not be limited to incident management, ramp control and metering, traveler information, value pricing, and transit service improvements.

The CMS in all TMAs are to be addressed during the metropolitan planning process certification reviews. If the TMA does not include a CMS that meets the requirements of 23 C.F.R. 500.109, deficiencies will be noted and corrections will need to be made.

**What should be reviewed related to an area's air quality conformity finding?**

In air quality non-attainment and maintenance areas, transportation plans, programs and projects cannot cause or contribute to new air quality violations, increase the frequency or severity of existing violations, or delay timely attainment of the identified standards [23 C.F.R. 450.216(a)(4) and 23 C.F.R. 450.330(b)]. Any significant changes in the design concept or scope (i.e., conversion of HOV lanes) of a project that has been already addressed and accommodated in a conforming Transportation Plan or TIP require that the viability of the existing conformity determination be re-evaluated. This reevaluation would be done through a new conformity analysis and determination of the transportation plan and the TIP and would be conducted by the Metropolitan Planning Organization (MPO) with input from the Environmental Protection Agency, FTA, FHWA, and state and local agencies. The MPO must submit its conformity finding to FHWA and FTA for a final conformity determination [40 C.F.R. Parts 51 and 93]. Additional information can be found in the FHWA publication titled A Transportation Conformity Reference Guide.

**What should be reviewed related to the State Implementation Plan?**

The Clean Air Act Amendments of 1990 contained a list of TCMs, including HOV lanes, which can be considered and included in a SIP to assist an area in attaining or maintaining National Ambient Air Quality Standards. Non-attainment and maintenance areas must provide for timely implementation of TCMs that are included in an approved SIP. If the HOV lane is included in the approved SIP as a TCM, a SIP modification, approved by EPA, will be required before it can be converted to a general purpose lane.

**What should be reviewed related to the results of the project's National Environmental Policy Act process?**

During the development of a project pursuant to the NEPA process, FHWA, FTA, and their partners may have made approval of the project subject to conditions and mitigation commitments. An agency proposing to convert an HOV lane to a general purpose travel lane will initiate a review of any such conditions and commitments contained in the project's Record of Decision or Finding of No Significant Impact, or in other agreements. This review will determine whether the original project's decision/approval is still valid or if the proposed conversion constitutes a new action.

In the latter case, the determination that the proposed conversion has the potential for environmental impacts that are new or greater in magnitude than those originally analyzed, or is in conflict with mitigation commitments, will require Federal approval of the action pursuant to 23 C.F.R. 771. The environmental documentation will be appropriate to the NEPA class of action and will include documentation regarding public/stakeholder involvement in decisions concerning the proposed conversion.

**What should be reviewed related to design or safety features?**

When a proposal is made to significantly change the operation of an HOV lane, an assessment is required on the existing and future impacts to the safety and operation of the facility. Agencies must ensure that appropriate geometric and other design features (such as cross-section, alignment, lane and shoulder
widths, access points, etc.) exist in support of the proposed new use. Agencies must satisfy the appropriate design standards and rectify any unsafe conditions that may be identified, prior to initiating any test or permanent change that may adversely affect the operation of an HOV lane.

**What should be reviewed related to limitations on the use of Federal funding?**

Several categories of Federal-aid funding have been and can be used to acquire right-of-way, or to design or construct HOV lanes. These categories have specific eligibility requirements and regulations that remain in effect even after the project is completed. Some funding categories cannot be used for the provision of additional roadway capacity in the form of unrestricted general purpose travel lanes. These categories include funds for the Congestion Mitigation & Air Quality Improvement (CMAQ) program [23 U.S.C. 149(b)], Interstate Maintenance program [23 U.S.C. 119(d)], and Mass Transit Capital Investment Grants [49 U.S.C. 5309(a)(1)(B)]. This restriction also applies if higher Federal participation ratios were used for the provision of HOV lanes with funds from the National Highway System (NHS) program, the Surface Transportation Program (STP), the Interstate 4R Discretionary program, the Interstate Construction program (23 C.F.R. 635), the Interstate Maintenance Discretionary Program, and Interstate the Discretionary program. (See Appendix A)

If funds from these programs were used to design or construct HOV lanes, any significant changes to the operation of an HOV lane, are not permitted. Repayment of a restricted class of funds previously expended on the project (payback) and the substitution of state funds or other authorized federal funds in an effort to overcome funding limitations is not permitted, unless specifically authorized by Federal statute, because FHWA currently lacks general statutory authority to permit payback of these funds and reobligation for a new purpose. As part of the documentation for any proposed action to significantly change the operation or convert an HOV lanes to a general purpose travel lane, the sources and amounts of Federal-aid funding used for the design and construction of the HOV lanes must be identified. An analysis must also be made of the requirements of the associated project agreements to determine if any other specific provisions have been established that may have further restricted the operation of the HOV lane.

Based on the results of this review, FHWA and FTA will determine if the proposed action complies with these requirements. If it is determined that the proposed action to significantly change the operation of the HOV lanes does not comply with these requirements, then the change will not be approved. If an agency implements a change which has been determined to be noncompliant with existing legislation or regulatory requirements, sanctions will be imposed by FHWA, consistent with 23 C.F.R. 1.36, including withholding further federal highway project approvals.

Additional information on the eligibility, funding, participation levels, and limitations related to the Federal-aid programs that may have been the source of funding to design or construct HOV lanes, can be found in Titles 23 (Highways) and 49 (Transportation) of U.S.C. and the FHWA publication titled "A Guide to Federal-Aid Programs and Projects." For high priority or demonstration projects, the federal legislation authorizing the project must be reviewed to obtain information related to any eligibility, funding, participation levels, or limitations. A summary of the regulatory requirements related to HOV lanes for the Federal-aid programs that are administered by FHWA is provided as Appendix A.

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**Section 3 -- Definitions**

The following definitions apply to terms used in this guidance:

(a) The term "agency" means any state or local agency which is considered to be the owner and operator of the HOV lanes or the adjoining transportation facility.
(b) The term "de-obligation" means a downward adjustment of previously reported obligations. De-obligations may occur due to less work being required that provided under a contract, cancellation of project or contract, initial obligation determined to be invalid, reduction of previously recorded estimate, corrections or duplicate obligations.

(c) The term "High-Occupancy Vehicle" means a motor vehicle, carrying at least two or more persons, including carpool, vanpools and buses.

(d) The term "HOV lane" means any preferential lane designated for exclusive use by high-occupancy vehicles (HOVs) for all or part of a day, including a designated lane on a freeway, other highway or a street, or independent roadway on a separate right-of-way.

(e) The term "HOV facility" means any kind of treatment that gives priority to buses, van pools, car pools and high-occupancy vehicles, including HOV lanes, park-and-ride lots, and other support facilities or elements.

(f) The term "HOV system" means any coordinated region wide network of integrated HOV facilities.

(g) The term "Inherently Low Emission Vehicles (ILEVs)" means any kind of vehicle which, because of the inherent properties of the fuel system design, will not have significant evaporative emissions, even if its evaporative emission control system has failed.

(h) The term "obligation" is a commitment of federal funds which creates a legal liability of the federal government for the payment of appropriated funds for goods and services ordered or received.

(i) The term "occupancy requirement" means any restriction that regulates the use of a facility for any period of the day based on a specified number of persons in a vehicle.

(j) The term "reobligation" means a new legal commitment of funds previously obligated for another specific purpose and deobligated.

Section 4 - References


Attachment 1:
Federal-aid Highway Funding for High Occupancy Vehicle (HOV) Lanes

The information contained in this appendix is intended to augment the FHWA program guidance on HOV lanes. This information summarizes the regulatory requirements found in Title 23, United States Code (23 U.S.C.) and the FHWA publication titled "A Guide to Federal-aid Programs and Projects" (Pub. No. FHWA-IF-99-006, May 1999). The key eligibility issues, funding participation ratios, and other limitations pertaining to HOV lanes have been compiled for the major Federal-aid programs that are administered by FHWA. In addition, the agreements that were developed for each improvement project should also be reviewed to determine the type of funds that were utilized, identify the Federal participation ratio, review any federal legislative requirements, or any other specific provisions that may have established further restrictions on the operation of the HOV lane or use of Federal-aid program funding.

National Highway System (NHS)

Status: Active

Background:

-Purpose is to provide an interconnected system of principal arterial routes which serve major population centers, international border crossings, ports, airports, public and other intermodal transportation facilities, and other major travel destinations; meet national defense requirements; and serve interstate and interregional travel.


Eligibility or Funding Issues:

-- Federal participation is 80% when NHS funds are used for constructing additional roadway capacity is added as general purpose travel lanes on the Interstate System, and for all types of work on non-Interstate routes.

-- Federal participation may be 90% when NHS funds are used for the addition of HOV or auxiliary lanes, but not any other types of lanes, to the Interstate System.

-- NHS funds may be used for HOV lanes and support facilities (e.g., carpool, vanpool, fringe or corridor parking, etc.).

--Significant operational changes are not permitted to HOV lanes that used NHS program funds for the design and construction of these lanes, if the funds were made available since ISTEA or TEA-21, at the higher Federal participation ratio (90%).

Surface Transportation Program (STP)

Status: Active

Background:

-- STP established in 1991 by Section 1007 of ISTEA and continued by TEA-21 (Public Law 105-178), to allocate funding based on the established apportionment formula.

Eligibility or Funding Issues:

-- Federal participation is 80% when STP funds are used for constructing additional roadway capacity is added as general purpose travel lanes on the Interstate System, and for all types of work on non-Interstate routes.

-- Federal participation may be 90% when STP funds are used for the addition of HOV or auxiliary lanes, but not any other types of lanes, to the Interstate System.

-- STP funds may be used for HOV lanes and support facilities (e.g., carpool, vanpool, fringe or corridor parking, etc.).

-- Significant operational changes are not permitted to HOV lanes that used STP program funds for the design and construction of these lanes, if the funds were made available from ISTEA or TEA-21, at the higher Federal participation ratio (90%).

Interstate 4R (I-4R) Program

Status: Inactive

Background:

-- Interstate 3R Program was established in the 1976 Federal-aid Highway Act which provided funding for resurfacing, restoring, and rehabilitating lanes on the Interstate system.

-- I-4R Program was expanded in 1981 with Federal-aid Highway Act, which included reconstruction as an eligible program item. It also allowed for projects included in the 1981 Interstate Cost Estimate (ICE) but no longer eligible for IC funding, and other work on the Interstate System that was no longer eligible for IC funding.

-- I-4R Program was discontinued with ISTEA in 1991, with the 3R components included in the new Interstate Maintenance (IM) Program. The NHS Program was developed to address the reconstruction portion of the I-4R program.

Eligibility or Funding Issues:

-- Federal participation 90%.

-- Prior to ISTEA, there were no limitations on roadway capacity expansion or funding restrictions associated with HOV lanes.

-- No funding restrictions exist with making significant operational changes to an HOV lane.

Interstate 4R Discretionary Program Funds

Status: Inactive

Background:

-- Established by Surface Transportation Assistance Act of 1982. Funds were originally derived from lapsed I-4R apportionments.


-- Program was continued in ISTEA by providing funding through set-asides from the NHS Program through 1997. Under ISTEA the I-4R Discretionary Program was separate and distinct from the IM Program. Funds were allowed to be used for resurfacing, restoring, rehabilitating and
reconstructing the Interstate system, including providing lanes for additional general purpose roadway capacity.

**Eligibility or Funding Issues:**

-- Federal participation is 90%.
-- ISTEA reduced Federal participation to 80% if any projects added new roadway capacity, unless this capacity was in the form of an HOV lane or auxiliary lane.
-- Prior to ISTEA, there were no limitations on roadway capacity expansion or funding restrictions associated with HOV lanes.
-- Significant operational changes are not permitted to HOV lanes that used I-4R Discretionary program funds for the design and construction of these lanes, if the funds were made available from ISTEA, at the higher Federal participation ratio (90%).

**Interstate Construction (IC) Program Funds (23 C.F.R. 476)**

**Status:** IC Program was last funded under ISTEA for 4 years, through FY 1995.

**Background:**

-- IC funding may be used for the initial construction of remaining portions of Interstate System.
-- Only work eligible under the Federal-aid Highway Act of 1981 and further limited eligibility for Interstate construction to the previously approved 1981 ICE.
-- ISTEA continued program through 1995 by providing final authorization of funding to complete construction. Only work allowable under the provisions of the Federal-aid Highway Act of 1981 and included in the ICE was eligible for IC program funding.

**Eligibility or Funding Issues:**

-- Surplus IC funds that have been transferred to other programs, are subject to the laws (regulations, policies and procedures) specific to this program.
-- Federal participation is 90%.
-- ISTEA reduced Federal participation to 80% if any projects added new roadway capacity, unless this capacity was in the form of an HOV lane or auxiliary lane.
-- Prior to ISTEA, there were no limitations on roadway capacity expansion or funding restrictions associated with HOV lanes.
-- Significant operational changes are not permitted to HOV lanes that used IC program funds for the design and construction of these lanes, if the funds were made available from ISTEA, at the higher Federal participation ratio (90%).

**Interstate Discretionary (ID) Program Funds**

**Status:** Active until funds allocated in FY 1999 are obligated, transferred, or lapsed. These were funds carried over from previous years.

**Background:**

-- 1978 Surface Transportation Assistance Act created the ID Program.
-- ID funds may be used for the same purposes as IC program. Only work allowable under the provisions of the Federal-Highway Act of 1981 and included in the 1981 ICE were eligible for ID program funding.
-- ID Program was discontinued with TEA-21 in 1998.
Eligibility or Funding Issues:

-- Allocations of funds must be obligated and administered in strict accord with the allocation memorandum.
-- Federal participation is 90%.
-- ISTEA reduced Federal participation to 80% if any projects added new roadway capacity, unless this capacity was in the form of an HOV lane or auxiliary lane.
-- Prior to change in ISTEA, there were no limitations on roadway capacity expansion or funding restrictions associated with HOV lanes.
-- Significant operational changes are not permitted to HOV lanes that used ID program funds for the design and construction of these lanes, if the funds were made available from ISTEA, at the higher Federal participation ratio (90%).

Interstate Maintenance (IM) Program

Status: Active.

Background:

-- Established by ISTEA in 1991 and replaced the 3R portions of the I-4R Program.
-- TEA-21 expanded the IM program to include reconstruction, with funding continuing to be ineligible for general purpose roadway capacity expansion, other than HOV lanes or auxiliary lanes.

Eligibility or Funding Issues:

- Federal participation is 90%.
- Significant operational changes are not permitted to HOV lanes that used IM program funds for design and construction.

Interstate Maintenance Discretionary (IMD) Program

Status: Active.

Background:

- Continuation of the I-4R Discretionary Program which was established by Section 115(a) of the Surface Transportation Assistance Act of 1982.

Eligibility or Funding Issues:

- Federal participation is 90%.
- TEA-21 reduced Federal participation to 80% if any projects added new roadway capacity, unless this capacity was in the form of an HOV lane or auxiliary lane.
- Significant operational changes are not permitted to HOV lanes that used IM Discretionary program funds for the design and construction of these lanes at the higher Federal participation ratio (90%).

Congestion Mitigation and Air Quality Improvement (CMAQ) Program

Status: Active.

Background:
Established in 1991 by ISTEA (Statutory reference, 23 U.S.C. 149). Program purpose is to fund projects and programs in air quality non-attainment and maintenance areas for ozone, carbon monoxide, and small particulate matter to reduce transportation related emissions.

Projects that add roadway capacity for general purpose travel are ineligible for funding, unless the project consists of an HOV facility that is available to general purpose traffic only at off-peak travel times.

Eligibility or Funding Issues:

Federal participation is 80% (90% if used on Interstate System).
Significant operational changes are not permitted to HOV lanes that used CMAQ program funds for design and construction.

High Priority or Federally Legislated Demonstration Projects

Status: Project and Legislation Specific

Background:

From 1970 until the passage of TEA-21 in 1998, Congress authorized over 1200 demonstration, priority, pilot, or special interest projects with earmarking of funds in various transportation authorization and appropriation acts.

Under TEA-21 Congress authorized funding for an additional 1850 specific projects under the High Priority Projects Program in 23 U.S.C. 117.

Congress continues to earmark funding for specific projects in annual appropriations acts, and, now that the High Priority Projects Program has been codified in Title 23, it is anticipated that Congress will continue to provide funding for additional specific projects in multi-year Transportation Bills (e.g., ISTEA, TEA-21, etc.).

Eligibility or Funding Issues:

Federal participation is generally 80% with some exceptions. The funds are available only for the work as described in legislation authorizing the project. These legislated project descriptions can be quite broad or very specific.
If the legislated project description specifies use of the funds for HOV lanes, significant operational changes to these HOV lanes would require additional congressional legislation, since the authorized funding was restricted to use for HOV lanes.
Appendix C
Managed Lane Signing Guidance

The following signing guidance is provided for managed lanes. The term managed lanes applies to single or multiple directional lanes restricted to HOVs and tolled or access controlled to manage demand in real time, in accordance with FHWA’s terminology for managed lanes. As such, all types of users, including trucks, may be eligible to use managed lanes, and signing on this dual roadway system need to conform as much as possible to freeway standards provided in the MUTCD. Signing guidance for this specific roadway application are drawn from current examples and the latest MUTCD guidance for HOV lanes (2003 edition).

Beginning of Project and Intermediate Entrance Ramps from Managed Lanes
Signing should include overhead mounted signs up to one mile in advance of beginning a project, with successive guide signing used up to the left side exit. If dynamic “value” pricing is applied, then the pricing information should be included on Dynamic Message Sign (DMS) panels at least once at each slip ramp access point. The DMS should provide cost information (either to the next exit or cost per mile), and travel time to a downstream landmark or major interchange, or average speed downstream. This information is needed to provide user with enough real-time information to make a decision to use the express lanes.

Example Dynamic Message Signing

[Image of dynamic message signs]

Note: Nomenclature for “Express Lanes” and whatever the tolling device is called is locally specific, and should be used in the banner indicated. In the absence of any local or statewide accepted publicly understood terminology, the closest terms from California’s toll and managed lanes have been borrowed in the illustrated examples due to their proximity to Nevada.
Example Signing for the Entrance to Barrier or Buffer Separated Managed Lanes

* EXPRESS LANES
** FREE ALL OTHERS
$0.50 PER MILE
55 MPH AT 8:10 A.M.

** EXPRESS LANES
** FREE ALL OTHERS
$0.50 PER MILE
55 MPH AT 8:10 A.M.

** EXPRESS LANES
** FREE ALL OTHERS
$0.50 PER MILE
55 MPH AT 8:10 A.M.

* 1 Mile and 2 Mile signs are optional

** For access restricted facilities, destinations may be augmented to accompany routes on Interchange Sequence signs.

NOT TO SCALE
End of Project and Intermediate Exit Ramps from Managed Lanes
Signing should include overhead mounted signs up to one mile in advance of the project terminus and intermediate exit ramps. Advance exits should be posted.

Example Managed Lane Exit Signing

Option 1 – With banner

Option 1 – Without banner

NOTE: Agency/Facility banner is being used on various facilities around the county.

The following illustrated layouts show typical signing conditions for an intermediate access drop ramp with potential park & ride facilities.
Example Signing for Direct Access with a Local Street or Park & Ride Facility
Example Signing For Direct Access from a Park & Ride Facility

NOT TO SCALE
The following illustrated layout shows typical guide signing conditions for a direct access flyover ramp.

**Example of Signing for Direct Access between HOV Lanes on Separate Roadways**

**NOTES:**
1. Additional advisory and warning signs are required.
2. Sign locations are approximate.
3. Variable occupancy limits vary between HOV facilities, they are occupancy levels that can be added to guide signs.
4. HOV facility could be barrier-separated, ladder-separated, or concurrent-flow from general purpose lane.
5. Distributing may be augmented to accompany non HOV traffic.

**For access separated facilities,**
Distributing may be augmented to accompany merge on ramp-change sequence signs.